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**Hilbers**

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(54) **AIR SPRING PRESSURE REGULATING VALVE**

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3,589,390 A \* 6/1971 Frantz ..... F16K 17/105  
137/489.5  
4,201,517 A \* 5/1980 Ferguson ..... F04B 49/022  
417/12  
4,254,634 A \* 3/1981 Akio ..... F25B 41/22  
62/217

(Continued)

**FOREIGN PATENT DOCUMENTS**

CN 204985892 U 1/2016  
CN 205036939 U 2/2016

(Continued)

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(56) **References Cited**

**U.S. PATENT DOCUMENTS**

2,401,144 A \* 5/1946 Dube ..... G05D 23/1856  
62/208  
3,541,593 A \* 11/1970 Weston ..... G05D 16/208  
209/726

**OTHER PUBLICATIONS**

Search Report from counterpart European Application No. 20203977.2, dated Mar. 9, 2021, 9 pp.

(Continued)

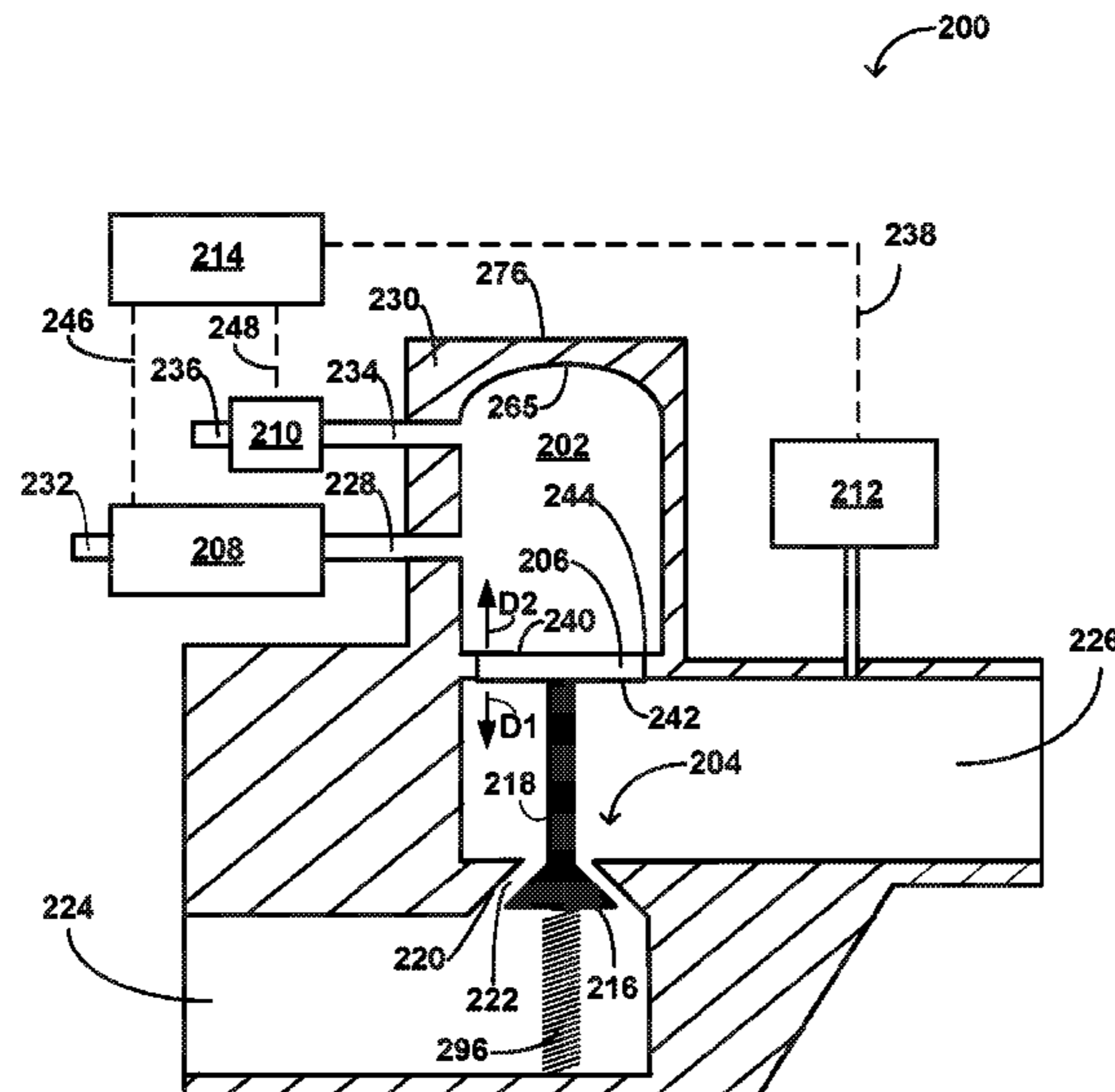
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(57) **ABSTRACT**

In some examples, a pressure regulating valve comprising a pressure chamber, a compressor configured to establish fluid communication with the pressure chamber, a vent valve configured to establish fluid communication with the pressure chamber, a pressure sensor, and a controller. The controller may determine a pressure based on the signal generated by the pressure sensor, and compare a pressure setpoint and the pressure. The controller may be configured to alter the pressure in the pressure chamber based on the comparison between the pressure setpoint and the pressure. For example, the controller may control the compressor to increase the pressure in the pressure chamber and/or control the vent valve to decrease the pressure in the pressure chamber. The altered pressure of the pressure chamber may generate movement of a restricting element within the pressure regulating valve.

**20 Claims, 7 Drawing Sheets**



(56)

**References Cited**

U.S. PATENT DOCUMENTS

4,442,680 A \* 4/1984 Barbier ..... G05D 16/166  
62/217  
5,348,036 A \* 9/1994 Oksanen ..... G05D 7/03  
137/1  
5,615,832 A \* 4/1997 Price ..... B05B 7/1404  
137/489.5  
5,624,394 A \* 4/1997 Barnitz ..... A61M 1/74  
604/67  
5,709,368 A \* 1/1998 Hajek, Jr. .... F15B 13/0405  
251/30.02  
5,810,657 A \* 9/1998 Pariseau ..... F24F 11/70  
454/61  
6,041,817 A \* 3/2000 Guertin ..... F16K 51/02  
137/565.23  
6,056,008 A \* 5/2000 Adams ..... G05D 16/2095  
137/487.5  
6,441,744 B1 \* 8/2002 Adams ..... G01F 1/363  
340/626  
7,089,733 B1 \* 8/2006 Jackson ..... F15B 11/165  
60/422  
2003/0070710 A1 \* 4/2003 Inayama ..... G05D 16/2095  
137/85  
2005/0279454 A1 \* 12/2005 Snijders ..... C23C 16/4412  
156/345.29

2007/0175513 A1 \* 8/2007 McLoughlin ..... G05D 16/208  
137/87.02  
2007/0207724 A1 \* 9/2007 Coogan ..... G05D 16/208  
454/238  
2008/0251146 A1 \* 10/2008 Folk ..... F16K 31/365  
137/624.27  
2009/0248210 A1 \* 10/2009 Arenas ..... G05D 16/2095  
700/282  
2014/0034133 A1 \* 2/2014 Beschorner ..... F15B 19/005  
137/1  
2016/0377192 A1 \* 12/2016 Renollett ..... F15B 5/006  
251/30.01  
2018/0046206 A1 \* 2/2018 Nguyen ..... G05D 16/2066

FOREIGN PATENT DOCUMENTS

EP 2132612 B1 9/2015  
EP 3100123 B1 12/2020  
KR 101602715 B1 3/2016

OTHER PUBLICATIONS

Response to European Search Report from counterpart European Application No. 20203977.2, dated Mar. 9, 2021, filed on Nov. 12, 2021, 82 pp.

\* cited by examiner

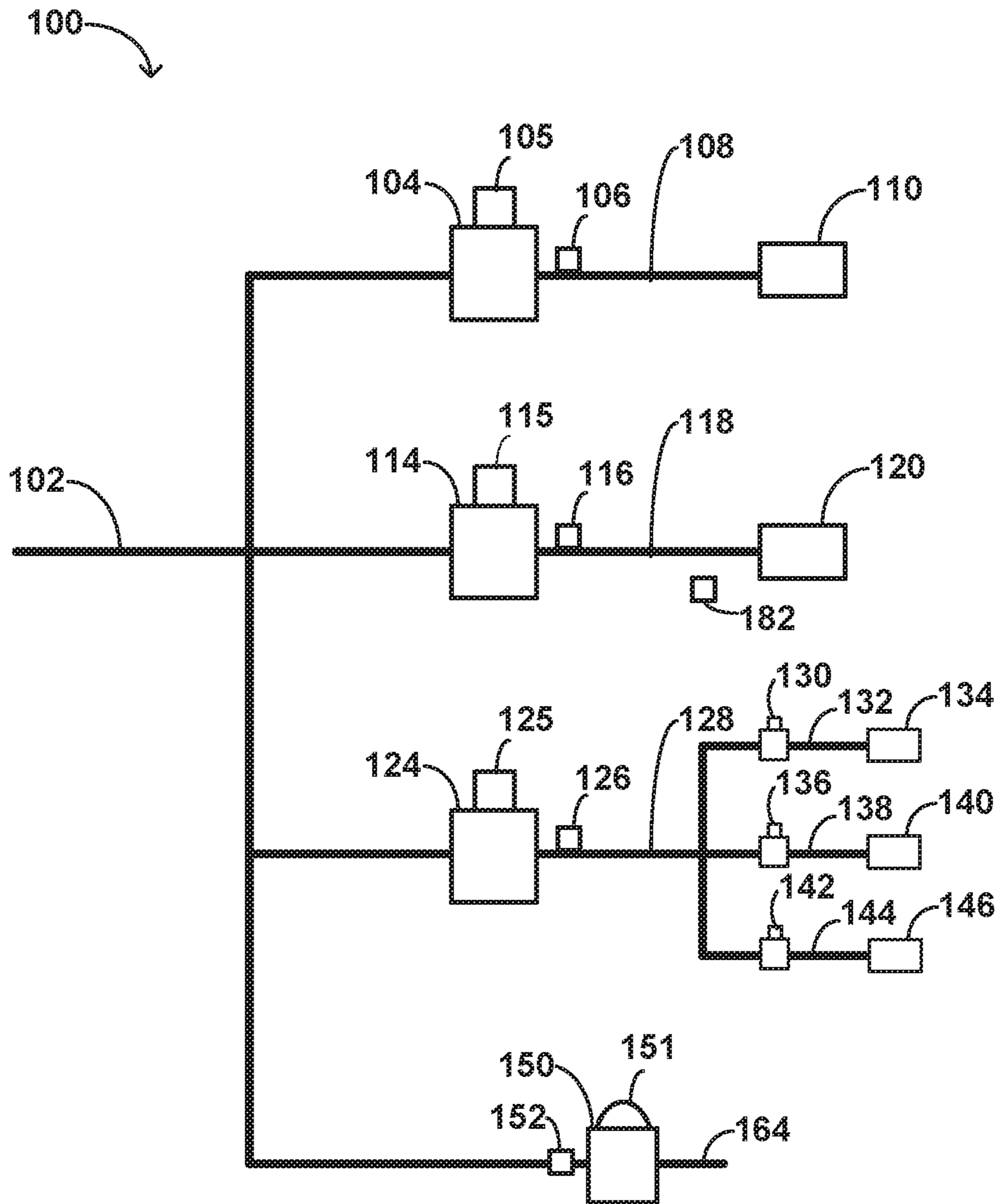


FIG. 1

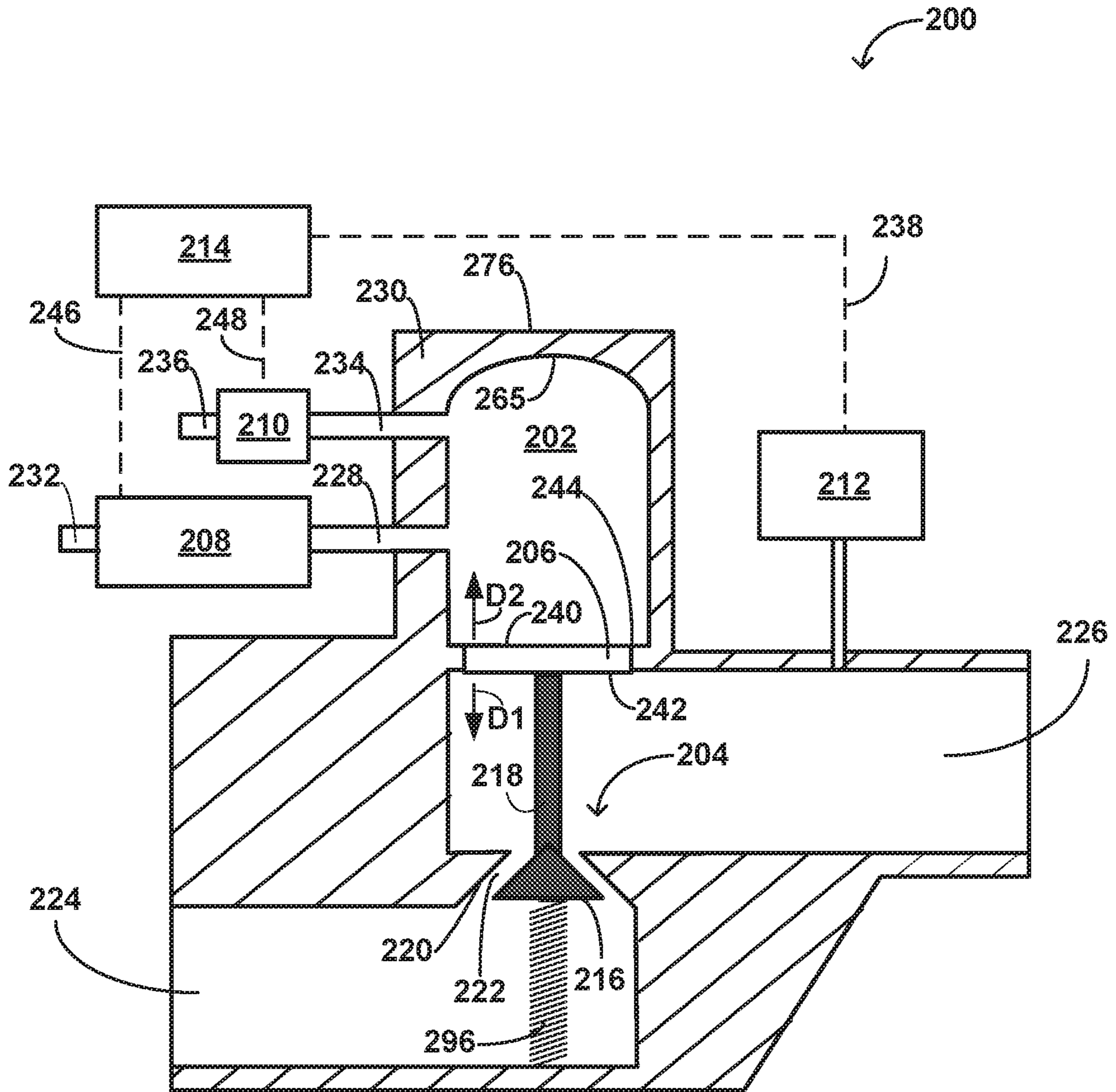


FIG. 2

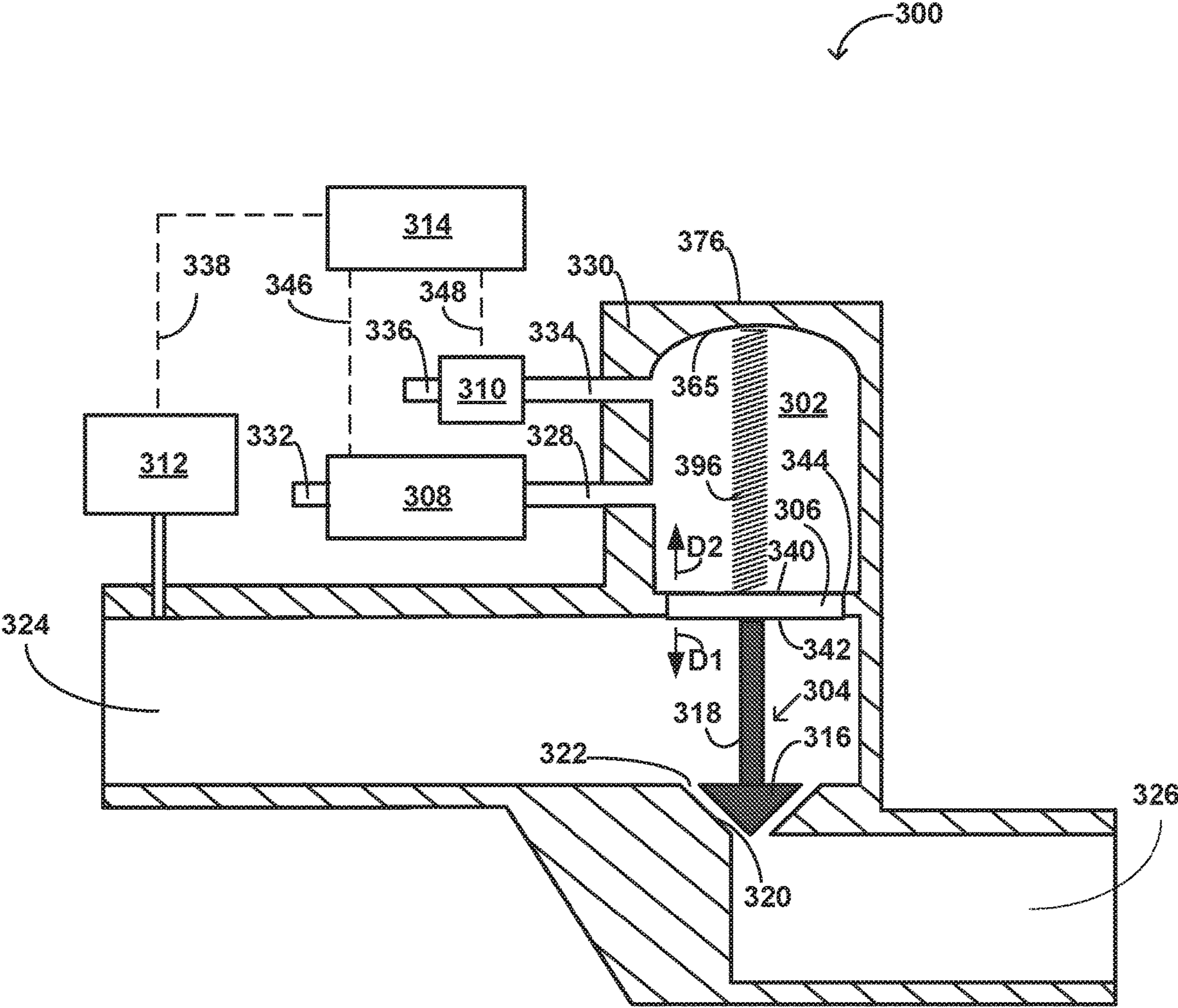


FIG. 3

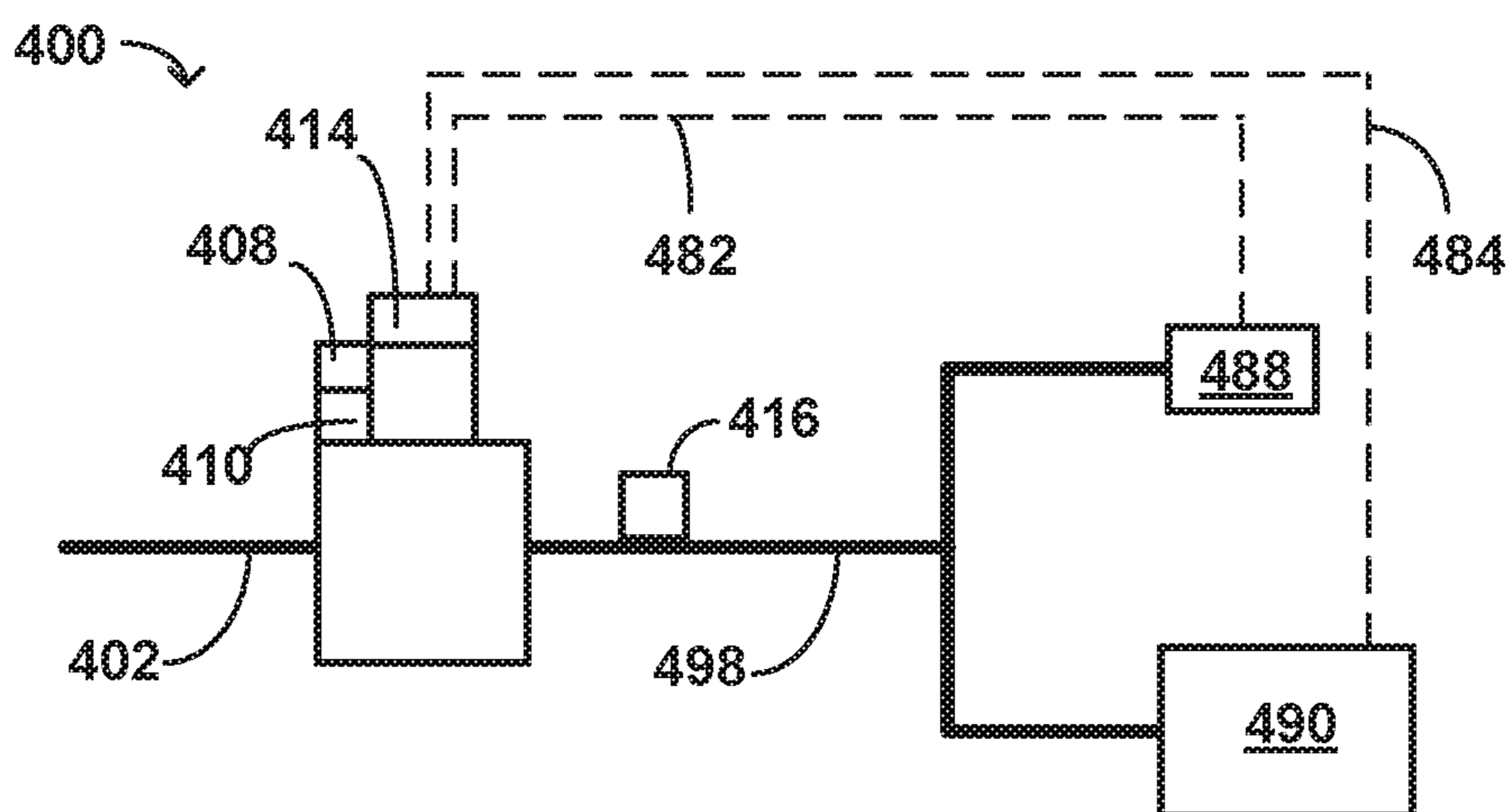


FIG. 4

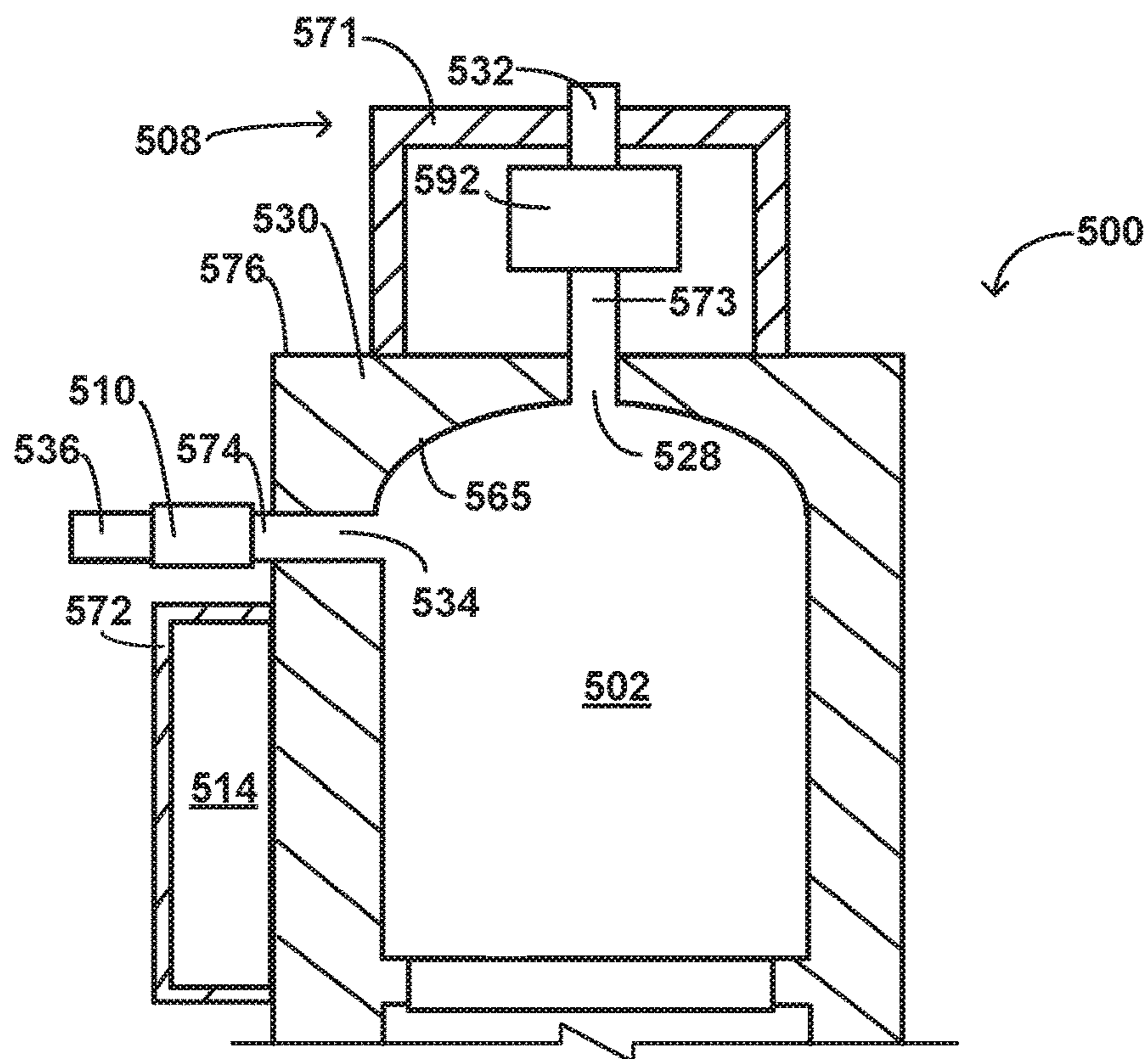


FIG. 5

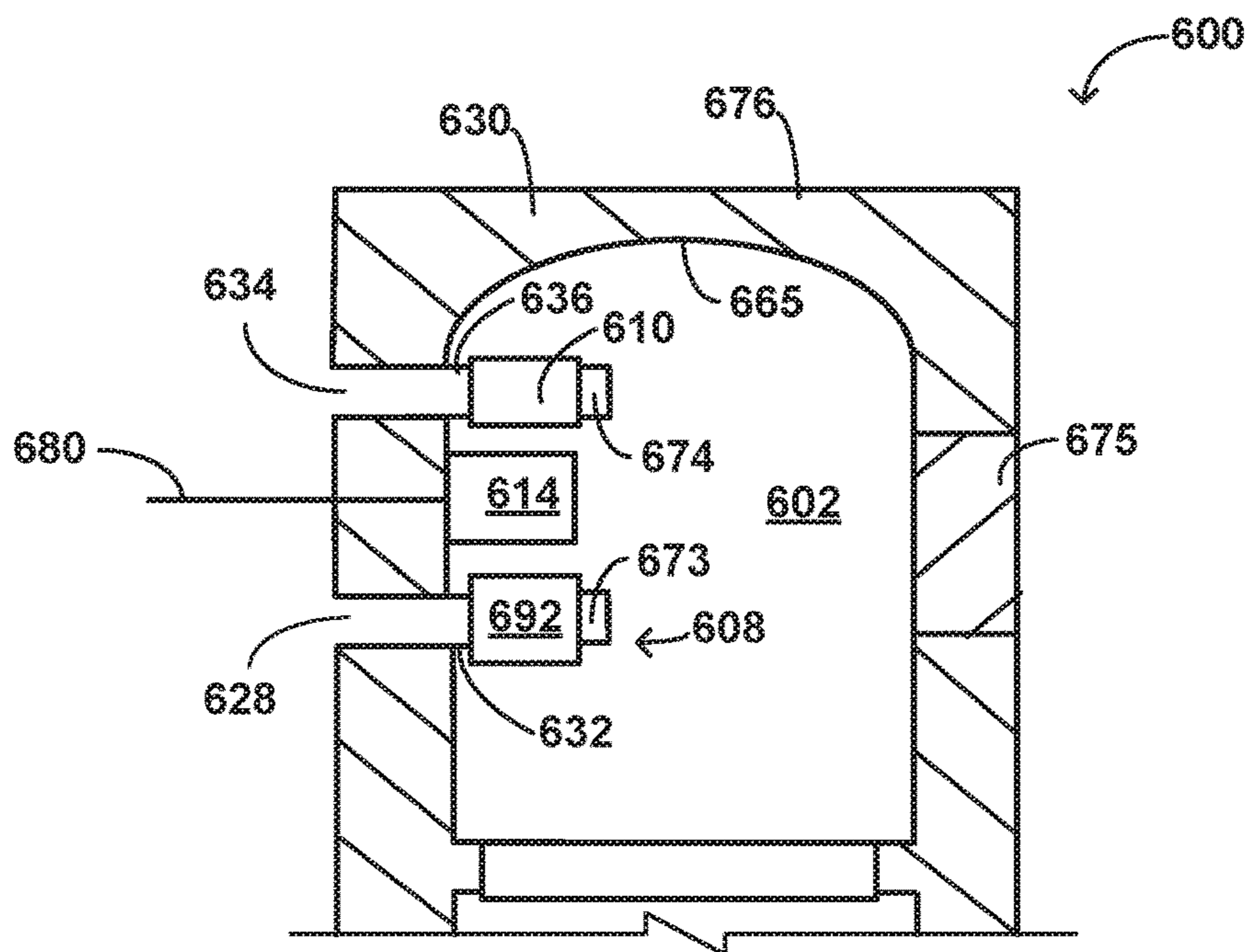


FIG. 6

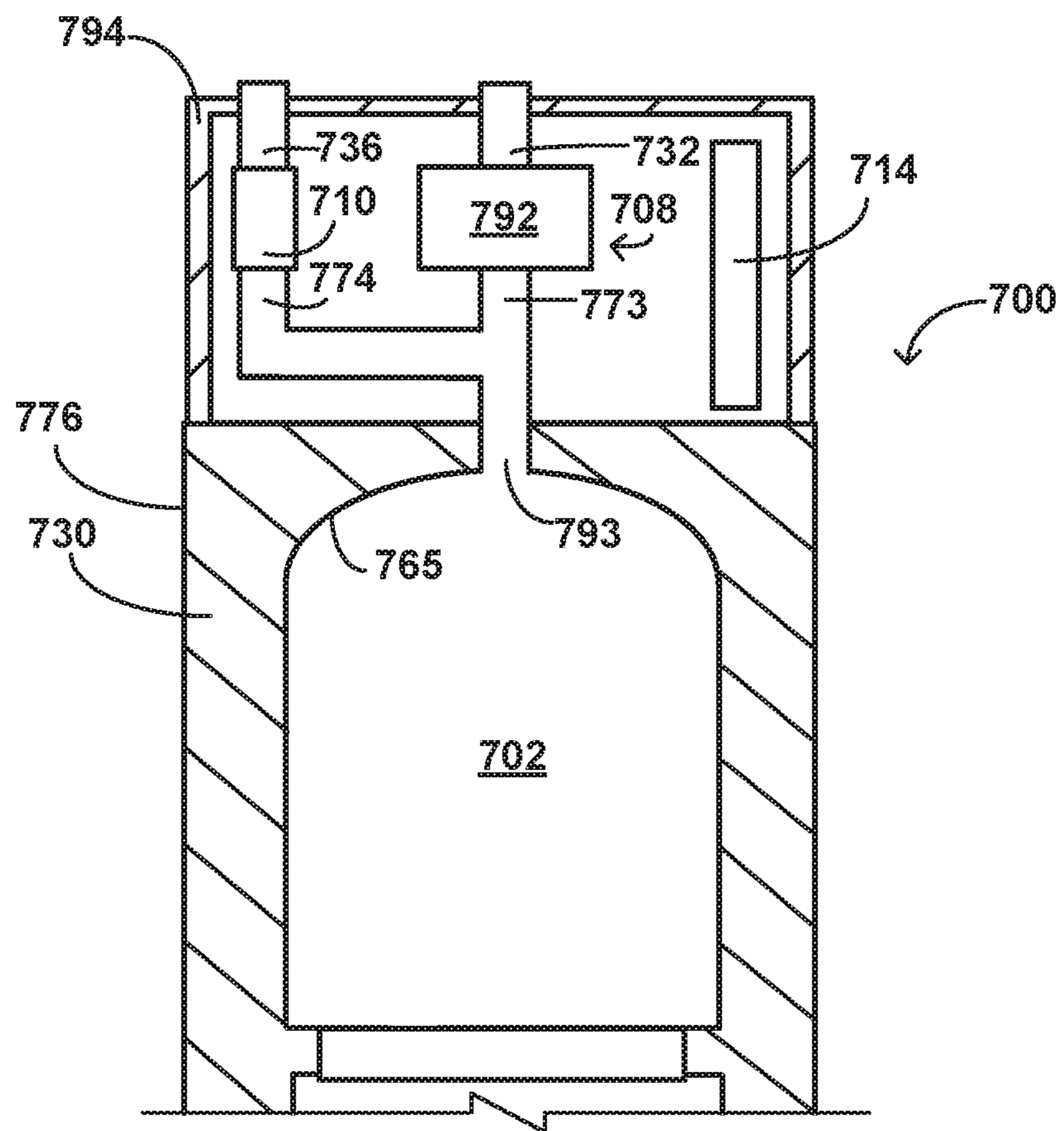


FIG. 7



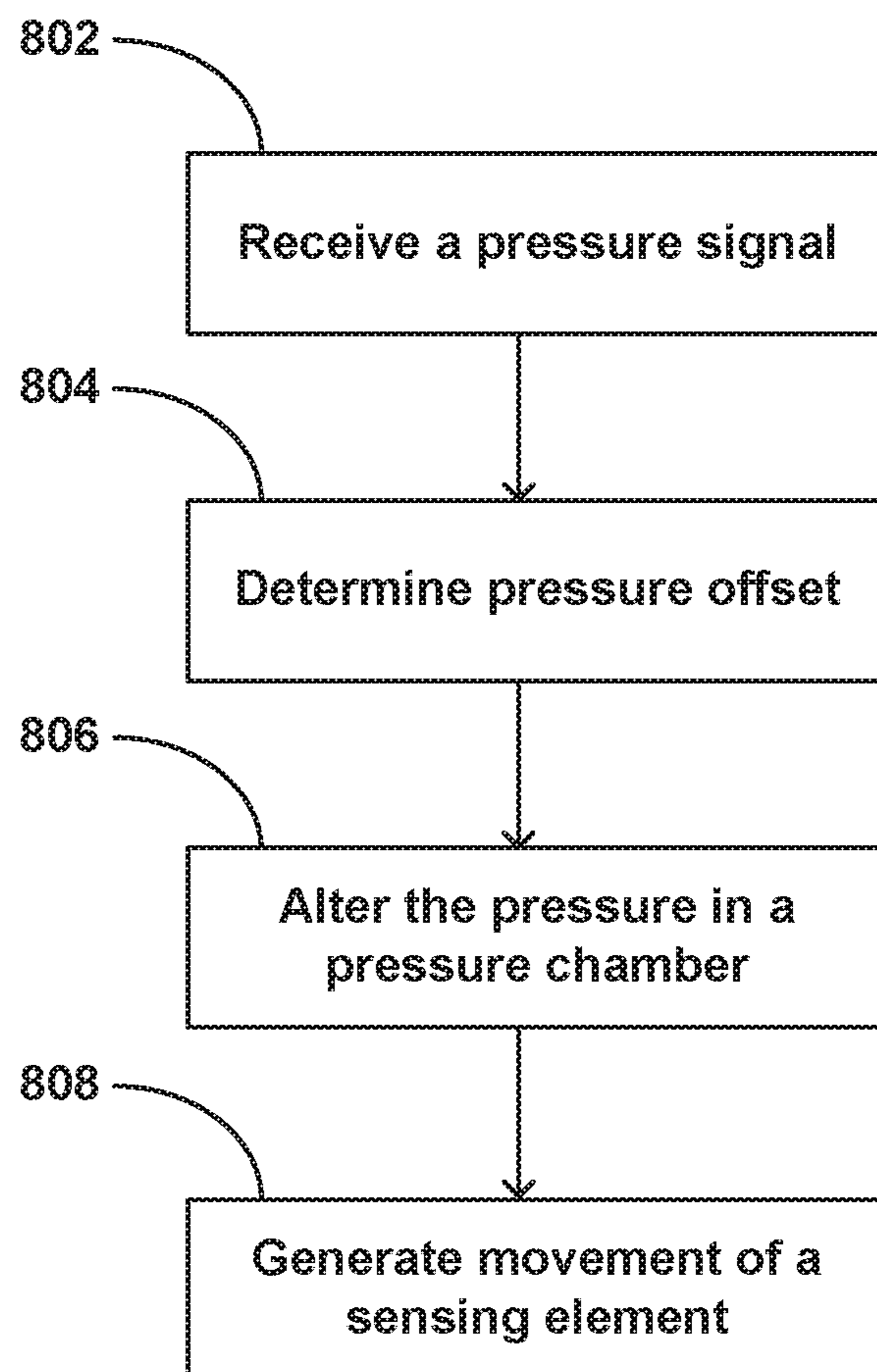


FIG. 8

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## AIR SPRING PRESSURE REGULATING VALVE

### TECHNICAL FIELD

The disclosure relates to pressure regulating valves.

### BACKGROUND

Pressure regulating devices are frequently used in industrial and residential systems designed to deliver fluid flows to one or more gaseous or liquid fluid loads. The pressure regulating devices may be employed to deliver or maintain the delivered fluid within predetermined pressure parameters selected based on, for example, system integrity, process controls, various equipment restrictions, and/or other reasons. Pressure regulating devices may operate by sensing pressure fluctuations and making corrective adjustments around a pressure setpoint. Such pressure regulating devices may be employed within fluid delivery systems to maintain pressures downstream or upstream of the device.

### SUMMARY

In examples described herein, a pressure regulating valve is configured to control a fluid pressure in a fluid circuit, such as piping header in a fluid distribution system, by at least controlling a pressure in a pressure chamber. The pressure regulating valve defines a flow area, through which fluid in the fluid circuit flows. A size of the flow area changes as a function of the pressure in the pressure chamber, and the size of the flow area affects the fluid pressure in the fluid circuit. Thus, the pressure regulating valve is configured to control the pressure in the fluid circuit by at least modifying the pressure in the pressure chamber. In some examples, the pressure regulating valve includes a controller configured to modify the pressure in the pressure chamber by at least controlling a compressor to increase the pressure in the pressure chamber and by at least controlling a vent valve to decrease the pressure in the pressure chamber. In some examples, increasing the pressure in the pressure chamber decreases the size of the flow area, which increases the fluid pressure through the valve, and decreasing the pressure in the pressure chamber increases the size of the flow area, which decreases the fluid pressure through the valve.

This disclosure also describes example techniques of using the pressure regulating valve to regulate a pressure.

Clause 1: A pressure regulating valve comprises a pressure chamber, a compressor configured to establish fluid communication with the pressure chamber, a vent valve configured to establish fluid communication with the pressure chamber, a pressure sensor configured to generate a signal indicative of a pressure, and a controller, the controller configured to determine a pressure setpoint for the pressure, determine the pressure based on the signal generated by the pressure sensor, compare the pressure setpoint and the pressure, and increase or decrease pressure in the pressure chamber based on the comparison of the pressure setpoint and the pressure, wherein the controller is configured to increase the pressure in the pressure chamber by at least controlling the compressor to increase pressure in the pressure chamber, and wherein the controller is configured to decrease the pressure in the pressure chamber by at least controlling the vent valve to decrease pressure in the pressure chamber.

Clause 2: The pressure regulating valve of clause 1, further comprising a restricting element and a sensing ele-

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ment in fluid communication with the pressure chamber, wherein the sensing element is configured to position in response to the pressure in the pressure chamber, and wherein the sensing element is configured to influence a position of the restricting element.

Clause 3: The pressure regulating valve of clause 1 or 2, wherein the restricting element comprises a valve disc, and wherein the pressure regulating valve further comprises a valve stem attached to the valve disc, a valve seat, and a flow area between the valve disc and the valve seat, wherein the sensing element is configured to translate the valve stem and alter the flow area in response to the controller increasing or decreasing pressure in the pressure chamber.

Clause 4: The pressure regulating valve of any of clauses 1 to 3, wherein the sensing element is configured to translate the valve stem and reduce the flow area in response to the controller increasing pressure in the pressure chamber, and wherein the sensing element is configured to translate the valve stem and increase the flow area in response to the controller decreasing pressure in the pressure chamber.

Clause 5: The pressure regulating valve of any of clauses 1 to 3, wherein the sensing element is configured to translate the valve stem and increase the flow area in response to the controller increasing pressure in the pressure chamber, and wherein the sensing element is configured to translate the valve stem and decrease the flow area in response to the controller decreasing pressure in the pressure chamber.

Clause 6: The pressure regulating valve of any of clauses 1 to 5 further comprising a spring element configured to translate the valve stem and reduce the flow area.

Clause 7: The pressure regulating valve of any of clauses 1 to 6 further comprising a valve inlet and a valve outlet, wherein the pressure regulating valve is configured to fluidly isolate the pressure chamber from the valve inlet and the valve outlet.

Clause 8: The pressure regulating valve of any of clauses 1 to 7 wherein the controller comprises a Proportional-Integral-Derivative (PID) controller, wherein the PID controller is configured to compare the pressure setpoint and the pressure, and use the pressure as a process variable.

Clause 9: The pressure regulating valve of any of clauses 1-8 wherein the controller is configured to receive a communication signal, and determine the pressure setpoint by at least associating the communication signal with a specific pressure.

Clause 10: The pressure regulating valve of any of clauses 1-9, wherein the controller is configured to receive a fluid leak signal, and increase or decrease the pressure in the pressure chamber to cause the sensing element to influence the restricting element to reduce or cease a flow through the pressure regulating valve in response to receiving the fluid leak signal.

Clause 11: The pressure regulating valve of any of clauses 1-11, wherein the wherein the pressure regulating valve comprises at least one of a poppet valve, a needle valve, a gate valve, a globe valve, a double-ported valve, or a spool valve.

Clause 12: A pressure regulating system comprising a valve comprising a pressure chamber, a valve inlet, a valve outlet, a sensing element in fluid communication with the pressure chamber, wherein the sensing element is configured to displace when a pressure in the pressure chamber increases or decreases, and a restricting element mechanically coupled to the sensing element, wherein the restricting element is configured to alter a flow area between the valve inlet and the valve outlet when the sensing element displaces, and a controller configured to determine a pressure

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setpoint, receive a signal indicative of a pressure, compare the pressure setpoint and the signal indicative of the pressure, control, based on the comparison, a compressor to increase the pressure in the pressure chamber and displace the sensing element and cause the restricting element to alter the flow area, and control, based on the comparison, a vent valve to decrease the pressure in the pressure chamber and displace the sensing element and cause the restricting element to alter the flow area.

Clause 13: The pressure regulating system of clause 12, wherein the sensing element comprises a diaphragm, a piston, or a diaphragm and a piston.

Clause 14: The pressure regulating system of clause 12 or 13, wherein the pressure comprises the pressure at the valve inlet, the system further comprising a pressure sensor configured to generate the signal indicative of the pressure at the valve inlet.

Clause 15: The pressure regulating system of any of clauses 12 through 14, further comprising a main valve comprising a main valve stem, wherein the valve is a pilot valve configured to control a position of the main valve stem.

Clause 16: The pressure regulating system of any of clauses 12 through 15, wherein the restricting element comprises a valve disc, and wherein the valve further comprises a valve stem mechanically coupling the valve disc to the sensing element, wherein the valve disc is configured to alter the flow area between the valve inlet and the valve outlet when the sensing element displaces.

Clause 17: The pressure regulating system of any of clauses 12 through 16, further comprising the compressor, the vent valve, and a pressure sensor configured to generate the signal indicative of the pressure at the valve inlet.

Clause 18: A method of regulating a pressure, the method comprising receiving, by a controller, a pressure signal indicative of a pressure, determining, by the controller, the pressure based on the signal, determining, by the controller, a pressure offset between the pressure and a pressure setpoint, altering, by the controller, a pressure in a pressure chamber of a pressure regulating valve based on the pressure offset by at least one of causing a compressor to increase the pressure in the pressure chamber, or causing a vent valve to vent the pressure chamber and decrease the pressure in the pressure chamber, wherein the altered pressure generates movement of a sensing element in fluid communication with the pressure chamber, and wherein the movement of the sensing element alters a flow area between a valve inlet and a valve outlet.

Clause 19: The method of clause 18, wherein receiving the pressure signal comprises receiving, by the controller, the pressure signal from a pressure sensor, wherein the pressure signal is indicative of a pressure at the valve inlet.

Clause 20: The method of clause 18 or 19, wherein movement of the sensing element alters the flow area by at least causing a restricting element to translate a valve stem and a valve disc, wherein the valve disc is in fluid communication with the flow area.

The details of one or more examples are set forth in the accompanying drawings and the description below. Other features, objects, and advantages will be apparent from the description and drawings, and from the claims.

#### BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a conceptual diagram illustrating an example fluid system.

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FIG. 2 is a conceptual diagram illustrating an example pressure regulating valve including a controller and an outlet pressure sensor.

FIG. 3 is a conceptual diagram illustrating an example pressure regulating valve including a controller and an inlet pressure sensor.

FIG. 4 is a conceptual diagram illustrating an example pressure regulating valve and a plurality of fluid loads.

FIG. 5 is a conceptual diagram illustrating an example pressure chamber of a pressure regulating valve.

FIG. 6 is a conceptual diagram illustrating another example of a pressure chamber of a pressure regulating valve.

FIG. 7 is a conceptual diagram illustrating an additional example of a pressure chamber of a pressure regulating valve.

FIG. 8 is a flow diagram illustrating an example technique for controlling a pressure in a fluid circuit.

#### DETAILED DESCRIPTION

Pressure regulating valves are used in industrial and residential applications to control a pressure of a fluid in a fluid circuit. In some example systems, pressure regulating valves are situated between a main, higher pressure circuit and one or more branch, lower pressure circuits. The pressure regulating valve so situated may manipulate fluid flows provided from the main circuit in order to compensate for increases or decreases in demand by the one or more branch circuits, increases in the pressure of the main circuit (e.g., a back-pressure regulator), or some other load disturbance or combination of load disturbances.

For example, in some water distribution systems, pressure regulating valves may be used between a pumping station and a piping network serving consumers, in order to maintain a substantially constant water pressure in the piping network as demand among consumers fluctuates. As another example, in some natural gas delivery systems, pressure regulating valves may be used to reduce gas pressure from transmission pipelines to a distribution tap serving farm for a community. Within industrial settings such as chemical processing plants, oil refineries, and the like, pressure regulating valves may be used between multiple primary and secondary branch circuits in order to control various processes involving the precise control of one or more fluids, or to provide relatively steady-state pressures to, for example, air or water service branches which experience unpredictable, transitory demands. Because many end-user fluid demands require the fluid to be delivered to a secondary branch or maintained in a main branch in accordance with predetermined pressure parameters, pressure regulating valves are often employed to substantially maintain downstream or upstream pressures.

In examples described herein, a pressure regulating valve (PRV) is configured to allow a flow of the fluid through the pressure regulating valve in order to substantially maintain the pressure at or near a pressure setpoint either upstream or downstream of the pressure regulating valve. For example, for downstream pressure control, the PRV may be configured to receive a higher pressure fluid at an inlet of the pressure regulating valve, reduce the pressure of the fluid as it flows through the valve using a restricting element (e.g., a valve disc), and provide a reduced pressure fluid to a fluid circuit in fluid communication with the pressure regulating valve outlet. The PRV may be configured such that the amount of pressure reduction caused by the restricting element is variable, based on a pressure setpoint. For

upstream pressure control, the PRV may be configured to receive a fluid at an inlet of the pressure regulating valve from a fluid circuit and reduce the pressure of the fluid circuit by at least providing a fluid discharge path from the fluid circuit. The flow area of the fluid discharge path may be controlled by a restricting element. The pressure regulating valve may be configured such that the amount of fluid discharged is dependent in part on a position of the restricting element, and the position of the restricting element may be variable and based on a pressure setpoint.

In examples described herein, a PRV is configured to control a fluid pressure in a fluid circuit by at least controlling a pressure in a pressure chamber, which affects the size of an area through which fluid flows through the pressure regulating valve. This area may be referred to herein as a flow area. The size (e.g., volume) of the flow area affects the fluid pressure in the fluid circuit. Thus, the PRV is configured to control the pressure in the fluid circuit by at least modifying the pressure in the pressure chamber. In some examples, the PRV includes a controller configured to modify the pressure in the pressure chamber by at least controlling a compressor to increase the pressure in the pressure chamber and by at least controlling a vent valve to decrease the pressure in the pressure chamber. In some examples, increasing the pressure in the pressure chamber decreases the size of the flow area, which increases the fluid pressure through the PRV, and decreasing the pressure in the pressure chamber increases the size of the flow area, which decreases the fluid pressure through the PRV.

In some cases, the PRV may be a normally open valve employed to substantially maintain a downstream pressure. The PRV may be configured to operate toward or into a closed position (e.g., by at least decreasing the volume of the flow area) as the downstream pressure increases, and operate toward or into an open position (e.g., by at least increasing the volume of the flow area) as the downstream pressure decreases. In this manner, the PRV may be configured to respond to downstream pressure. Decreasing downstream pressures may be indicative of an increase in demand, prompting the PRV to operate toward or into an open position to allow more flow to a downstream branch circuit. On the other hand, increasing downstream pressures may be indicative of a decrease in demand, prompting the PRV to operate toward or into a closed position to provide less flow to the downstream branch circuit. By treating downstream pressure as a proxy for demand in this manner, the PRV may substantially match the fluid supply from a main circuit to the fluid demand generated in the branch circuit, while substantially maintaining a set pressure downstream of the PRV.

In some cases, the PRV may be a normally closed valve employed to substantially maintain an upstream pressure (e.g., a back-pressure regulator (BPR)). The PRV may be configured to travel in an opening direction as the upstream pressure increases, and travel in a closing direction (or remain closed) as the upstream pressure decreases. Increasing upstream pressure may prompt the PRV to travel in the open direction, in order to allow increased flow through the flow area and decrease the upstream pressure. Decreasing downstream pressures may prompt the PRV to travel in the closing direction (or remain closed), in order to decrease flow through the flow area (or maintain substantially no flow) and increase the upstream pressure. In this manner, the PRV may be configured to substantially maintain pressure in an upstream supply branch while substantially matching demand from fluid loads drawing from the supply branch.

Some PRVs include a restricting element configured to help control flow from a higher pressure main circuit to a lower pressure branch circuit. The restricting element may comprise a valve member serving as a movable obstruction within a flow area of the PRV valve. The restricting element may comprise a valve disc, a valve spool, and/or some other movable obstruction which acts in combination with other components of the valve to provide a flow area. A fluid flowing through the PRV experiences a pressure decrease (e.g., head loss) as it proceeds through the PRV flow area due at least in part to the obstructing restricting element. The PRV may translate the restricting element to alter the spatial and/or obstruction characteristics of the flow area, which may alter the pressure loss experienced by the fluid as it travels through the PRV. Control of this pressure drop through the PRV allows control of a downstream or upstream pressure when the pressure regulating valve bridges a higher pressure main circuit and a lower pressure branch circuit. The restricting element generating the fluid pressure loss may be, for example, a poppet valve, a needle valve, a gate valve, a globe valve, spool valve, or some other mechanism or combination of mechanisms. The restricting element may be a double-ported valve.

A PRV may further include a sensing element configured to translate the restricting element, in order to vary a pressure drop and/or a flow area as a fluid flows through the pressure regulating valve. The sensing element may be, for example, a diaphragm or piston mechanically coupled to the restricting element, such that movement of the diaphragm or piston generates a translation of the restricting element. The PRV may be configured such that changes in an upstream or downstream pressure cause the sensing element to influence the restricting element and alter the flow area of the pressure regulating in a specific manner. For example, the PRV may be configured such that, when downstream pressure increases, the sensing element translates the restricting element to decrease the flow area of the PRV and consequently increase the pressure loss of a fluid flowing through the flow area, in order to cause a decrease in the downstream pressure. The PRV may be configured such that, when downstream pressure decreases, the sensing element translates the restricting element to increase the flow area of the PRV and consequently decrease the pressure loss of a fluid flowing through the flow area, in order to cause an increase in the downstream pressure. In some examples—such as when the PRV acts as a BPR—the PRV may be configured such that when an upstream pressure increases, the sensing element translates the restricting element to increase the flow area of the PRV and consequently decrease the upstream pressure.

In some examples, the degree of movement of the sensing element in response to changes in the upstream or downstream pressure may be influenced by a dome having a pressure chamber. The pressure chamber may hold a gas at a specific gas pressure, and be configured such that the gas pressure acts on one side of the sensing element. Adjustments to the gas pressure alter the degree of movement the sensing element experiences in response to changes in an upstream or downstream pressure, and allows the PRV to control the pressure setpoint around which the PRV operates. The PRV may include a compressor in fluid communication with the pressure chamber to increase a pressure in the pressure chamber, and may include a vent valve in fluid communication with the pressure chamber to decrease a pressure in the pressure chamber. The PRV may include a controller configured to cause the compressor and/or the vent valve to adjust the pressure in the pressure chamber, to enable the controller to direct changes in setpoint pressures.

In some examples, the PRV may be configured to receive a fluid flow from an upstream fluid branch and provide the fluid flow to a downstream branch while substantially maintaining a pressure in a downstream branch based on a current pressure setpoint. Thus, in some examples, in response to receiving a revised pressure setpoint less than the current pressure setpoint, the controller of the PRV may decrease the downstream pressure by at least controlling the compressor or the vent valve to modify the pressure in the pressure chamber in order to translate the restricting element to increase a pressure loss of the fluid flowing through the valve to the downstream branch (e.g., translate the restricting element in a closing direction). In addition, in response to receiving a revised pressure setpoint greater than the current pressure setpoint, the controller is configured to increase the downstream pressure by at least controlling the compressor or the vent valve to modify the pressure in the pressure chamber to translate the restricting element to decrease a pressure loss of the fluid flowing through the valve to the downstream branch (e.g., translate the restricting element in an opening direction).

In some examples, the PRV may be configured to act as a back-pressure regulator and substantially maintain a pressure in fluid branch upstream of the PRV based on a current pressure setpoint. Thus, in some examples, in response to receiving a revised pressure setpoint less than the current pressure setpoint, the controller of the PRV decreases the upstream pressure by at least controlling the compressor or the vent valve to modify the pressure in the pressure chamber in order to translate the restricting element to increase the flow area of the PRV and increase the flow from the upstream branch. In addition, in response to receiving a revised pressure setpoint greater than the current pressure setpoint, the controller of the PRV decreases the upstream pressure by at least controlling the compressor or the vent valve to modify the pressure in the pressure chamber in order to translate the restricting element to decrease the flow area of the PRV and decrease or even cease (in some examples) flow from the upstream branch.

In some examples, a PRV may be configured to operate around a specific pressure setpoint. The PRV may be configured to substantially maintain a setpoint pressure in a fluid branch downstream of the PRV, or may be configured to substantially maintain a setpoint pressure in a fluid branch upstream of the PRV, such as with the aid of a sensing element and a restricting element.

Here and elsewhere, “downstream” means the direction of a fluid flowing from a higher pressure area to a lower pressure area. “Upstream” denotes a direction opposite the downstream direction. For example, when a PRV is configured to provide flow from a higher pressure main circuit to a lower pressure branch circuit, a fluid flowing from the higher pressure main circuit to the lower pressure branch circuit flows in the downstream direction. The direction opposite the direction of fluid flow from the higher pressure main circuit to the lower pressure branch circuit is the upstream direction.

FIG. 1 illustrates an example fluid system 100 including a main circuit 102 configured to provide a fluid (gas or liquid) to branch circuits 108, 118, and 128. Branch circuit 108 is configured to be supplied with a fluid from main circuit 102 via PRV 104, and configured to provide the fluid to fluid load 110. PRV 104 is configured to receive higher pressure fluid from, for example, main circuit 102, and supply the fluid at a lower pressure to branch circuit 108. Branch circuit 108 is configured to provide the lower pressure fluid to fluid load 110.

Fluid load 110 may be a load intended to receive fluid at some secondary pressure below the supply pressure of the fluid provided by main circuit 102. For example, fluid load 110 might be a water or air connection intended to operate under relatively constant or transitory demand, where equipment and/or safety considerations require that the air or water be provided at a lower pressure than that present within main circuit 102. Fluid load 110 might be, for example, a primary residential water connection, a water supply to a specific household appliance such as a water heater, a service air connection for the operation of air-driven tools, a pneumatic supply to some pneumatically operated system, a cooling water supply to specific equipment, or some other load intended to operate at pressures lower than that supplied by main circuit 102.

PRV 104 is configured to receive the higher pressure fluid from main circuit 102 and provide the fluid at a lower pressure to branch circuit 108. PRV 104 is configured to operate in accordance with a specific pressure setpoint, in order to maintain a substantially constant secondary pressure in branch circuit 108 as the main supply pressure of main circuit 102 varies and/or the fluid demand from fluid load 110 varies. For example, PRV 104 may be configured to maintain a secondary pressure in branch circuit 108 within 1% to about 30% of a setpoint pressure, such as within 30% of the pressure setpoint, within 20% of the pressure setpoint, within 10% of the setpoint pressure, within 5% of the setpoint pressure, or within 1% of the setpoint pressure.

PRV 104 may comprise a gas loaded, spring loaded, or gas and spring loaded dome, such as dome 105. Dome 105 may impart a pressure and/or force to a sensing element (not shown in FIG. 1) within PRV 104. The sensing element may be configured such that some portion of the fluid flow proceeding through PRV 104 imparts a pressure generally counter-acting the pressure and/or force imparted by dome 105. The sensing element may be configured to translate in response to changes in the dome pressure and/or force, changes in the counter-acting pressure of the fluid flow through PRV 104, or changes to both. The translation of the sensing element may alter the fluid flow characteristics of the flow through PRV 104, and act to increase or decrease a pressure of branch circuit 108. Dome 105 may be configured such that the pressure and/or force imparted by dome 105 is adjustable. Adjustments to the pressure and/or force imparted by dome 105 may thus be utilized as a control for the pressure setpoint of branch circuit 108. For example, the force applied by dome 105 is configured to be adjusted by increasing or decreasing a gas pressure with a pressure chamber comprising dome 105. As discussed below, in some examples, PRV 104 includes a compressor and a vent valve, and a controller of PRV 104 is configured to control the compressor to increase a gas pressure in the pressure chamber of dome 105, and control a vent valve to reduce a gas pressure in the pressure chamber of dome 105. The controller of a PRV, as described herein, can be located within a housing of the PRV or can be separate from the housing of the PRV. For example, the controller of PRV 104 can be located within a housing of PRV 104 or be positioned elsewhere within system 100. Further, although controllers of individual PRVs of system 100 are described herein, in some examples, one controller can control multiple PRVs. That is, system 100 can include one or more controllers configured to provide the control of PRVs described herein.

Pressure sensor 106 is configured to provide an indication of a pressure at a location within branch circuit 108, a pressure at an outlet of PRV 104, or a pressure at some other location in fluid communication with branch circuit 108. For

example, pressure sensor **106**, as well as other pressure sensors described herein, can include any suitable pressure sensing circuitry and other structure configured to generate a signal indicative of the pressure at the sensing location. In some examples, a controller (e.g., of PRV **104**) can adjust the dome **105** of PRV **104** based on the indication provided by pressure sensor **106**. For example, pressure sensor **106** may indicate a first pressure of branch circuit **108**. In order to substantially establish a second (higher or lower) pressure in branch circuit **108**, the controller can adjust the gas pressure within a pressure chamber comprising dome **105** until pressure sensor **106** substantially indicates the second pressure.

System **100** may include additional branch circuits, such as branch circuit **118**. Branch circuit **118** is configured to receive fluid from main circuit **102** via PRV **114** and provide fluid to fluid load **120**. PRV **114** and fluid load **120** may be similar to PRV **104** and fluid load **110**. For example, fluid load **120** may be a load intended to receive fluid at some particular pressure below the supply pressure of the fluid provided by main circuit **102**, and PRV **114** may be configured to substantially maintain the particular pressure in branch circuit **118**. The particular pressure based on fluid load **120** may be greater, less than, or equal to the predetermined pressure based on fluid load **110**. Correspondingly, a particular pressure setpoint of PRV **114** may be greater, less than, or equal to the specific pressure setpoint of PRV **104**. PRV **114** may be configured to operate similarly to PRV **104**, such that PRV **114** may substantially maintain the particular pressure within branch circuit **118** as the main supply pressure of main circuit **102** and/or the fluid demand from fluid load **120** varies. PRV **114** may comprise dome **115**, and pressure sensor **116**, which is configured to generate an indication of a pressure at a location within branch circuit **118**, a pressure at an outlet of PRV **114**, or a pressure at some other location in fluid communication with branch circuit **118**.

System **100** may further include a branch circuit **128**. Branch circuit **128** may receive fluid from main circuit **102** via PRV **124**. PRV **124** may be configured to operate similarly to PRV **104** and PRV **114**, such that PRV **124** may substantially maintain an established pressure within branch circuit **128** as the main supply pressure of main circuit **102** and/or downstream fluid demands vary. PRV **124** may comprise dome **125**, and pressure sensor **126**, which is configured to generate an indication of a pressure at a location within branch circuit **128**, a pressure at an outlet of PRV **124**, or a pressure at some other location in fluid communication with branch circuit **128**.

PRV **124** may act as a primary pressure regulator and provide fluid at an established pressure to secondary pressure regulator **130**, secondary pressure regulator **136**, and secondary pressure regulator **142**. Secondary pressure regulator **130** may be configured to further reduce the pressure of the fluid within branch circuit **128** and provide fluid to tertiary branch **132** and fluid load **134**. Secondary pressure regulator **136** may be configured to further reduce the pressure of the fluid within branch circuit **128** and provide the fluid to tertiary branch **138** and fluid load **140**. Secondary pressure regulator **142** may be configured to further reduce the pressure of the fluid within branch circuit **128** and provide the fluid to tertiary branch **144** and fluid load **146**. Fluid load **134**, fluid load **140**, and fluid load **146** may require fluid supplied at pressures less than fluid load **110** and/or fluid load **120**, and secondary regulator **130**, secondary regulator **136**, and secondary regulator **142** may be provided in order accomplish the additional pressure reduc-

tion in a more accurate manner based on, for example, a droop or other inaccuracy which may occur during operation of PRV **124**. For example, PRV **124** might be used to reduce a main supply pressure of about 500 psi (4.35 megapascal) in main circuit **102** to a secondary pressure of about 100 psi (689 kilopascal (kPa)) in branch circuit **128**, and secondary pressure regulators **130**, **136**, **142** might be used to reduce the secondary pressure of about 100 psi (689 kPa) in branch circuit **128** to a pressure less than about 25 psi (172 kPa).

In some examples, system **100** includes one or more additional PRVs, such as PRV **150**, to act as a back-pressure regulator and operate in accordance with a specific pressure setpoint, in order to maintain a substantially constant main supply pressure of main circuit **102** as the fluid demands of PRV **104**, PRV **114**, and PRV **124** vary. PRV **150** may be configured to provide a relieving flow from main circuit **102** via, for example, fluid conduit **164** when a pressure of main circuit **102** exceeds a pressure setpoint. For example, PRV **150** may be configured to open or further open when the main supply pressure of main circuit **102** equals or exceeds a setpoint value, in order to provide a relieving flow from main circuit **102** via fluid conduit **164**. PRV **150** may be configured to close when the main supply pressure of main circuit **102** equals or is below the setpoint valve, and/or further close as the main supply pressure of main circuit **102** approaches the setpoint value from an over pressure condition in main circuit **102**.

In some examples, PRV **150** comprises a gas loaded, spring loaded, or gas and spring loaded dome, such as dome **151**. Dome **151** may impart a pressure and/or force to a sensing element (not shown) within PRV **150**. The sensing element may be configured such that the pressure of main circuit **102** (upstream of PRV **150**) counter-acts the pressure and/or force imparted by dome **151**. The sensing element may be configured to translate in response to changes in the dome pressure and/or force, changes in the pressure of main circuit **102**, or changes to both. PRV **150** may be configured such that the pressure and/or force imparted by dome **151** is adjustable. Adjustments to the pressure and/or force imparted by dome **151** may thus be utilized as a control for the pressure setpoint of branch circuit **108**. For example, a controller, e.g., of PRV **150**, can adjust a pressure provided by dome **151** by increasing or decreasing a gas pressure with a pressure chamber comprising dome **151**.

Pressure sensor **152** is configured to generate an indication of a pressure at a location within main circuit **102**, a pressure at an inlet of PRV **151**, or a pressure at some other location in fluid communication with main circuit **102**. The controller can adjust dome **151** of PRV **150** based on the indication provided by pressure sensor **152**. For example, pressure sensor **152** may indicate a first pressure of main circuit **102**. In order to substantially establish a second (higher or lower) pressure in main circuit **102**, the controller can adjust a gas pressure within a pressure chamber comprising dome **151** until pressure sensor **152** substantially indicates the second pressure.

As discussed, pressure regulating valves such as some or all of PRV **104**, PRV **114**, PRV **124**, PRV **130**, PRV **136**, PRV **142**, and PRV **150** may include a respective restricting element in order to control flow from a higher pressure main circuit such as main circuit **102** to a lower pressure branch circuit or fluid conduit. The restricting element may comprise a valve member serving as a movable obstruction within a flow area of the PRV. The restricting element may comprise a valve disc, a valve spool, and/or some other movable obstruction which acts in combination with other components of the PRV to provide the flow area. A fluid

flowing through the PRV from a PRV inlet to a PRV outlet experiences a pressure decrease (e.g., head loss) as it proceeds through the flow area, due at least in part to the obstruction in the flow area provided by the restricting element. Movement of the restricting element, which can be referred to herein as PRV travel in some examples, may alter the obstruction provided by the restricting element, which may alter the pressure loss experienced by the fluid as it travels through the pressure regulating valve. The alteration of the restricting element may include a restricting element position corresponding to fully open, fully closed, and/or any position between fully open and fully closed. Control of the pressure drop through the valve using the restricting element allows control of a downstream or upstream pressure when the pressure regulating valve bridges a higher pressure main circuit and a lower pressure branch circuit.

Although PRVs **104**, **114**, **124**, **130**, **136**, **142**, **150**, are shown in FIG. 1, system **100** may include any suitable number of pressure regulating valves, and any number of main, branch, or otherwise designated fluid branches. The pressure regulating valves may be configured to receive a higher pressure fluid from a first branch and provide fluid to a second branch while substantially maintaining a pressure in the second branch. In some examples, some or all of the PRVs may be configured to as a back-pressure regulator and discharge fluid from a first branch to a second branch and/or fluid path to substantially maintain a pressure in the first branch. A PRV may supply any number of fluid loads and any number of fluid branches. For example, PRV **104** may supply one or more fluid loads in addition to fluid load **110** and one or more fluid branches in addition to branch circuit **108**. A main, branch, or otherwise designated fluid branch may receive fluid from any number of upstream pressure regulating valves. Any number of pressure regulating valves may operate in in series or in parallel with any quantity of pressure regulating valves.

FIG. 2 illustrates an example PRV **200**. PRV **200** comprises PRV inlet **224** and PRV outlet **226** and is configured to provide a flow path for a fluid between PRV inlet **224** and PRV outlet **226**. In some examples, PRV **200** is configured to receive a higher pressure fluid at PRV inlet **224** and regulate the fluid flow in order to provide fluid at a lower pressure at PRV outlet **226**. For example, PRV **200** may be configured receive a higher pressure fluid from main circuit **102** and provide a lower pressure fluid to branch circuit **108**, branch circuit **118**, or branch circuit **128** (FIG. 1). Thus, PRV **200** is an example of any of the PRVs described with reference to FIG. 1 (e.g., PRV **104**, PRV **114**, PRV **124**, PRV **130**, PRV **136**, PRV **142**, and/or PRV **150**)

In the example shown in FIG. 2, PRV further comprises restricting element **204**, valve disc **216**, valve stem **218**, valve seat **220**, sensing element **206** defining first side **240**, second side **242**, and perimeter **244**, pressure chamber **202**, housing **230** having a housing exterior **276** and a boundary **265**, controller **214**, pressure sensor **212**, compressor **208**, compressor conduit **228**, compressor inlet **232**, vent valve **210**, vent valve outlet **236**, vent conduit **234**, sensor communication link **238**, compressor communication link **246**, vent valve communication link **248**, and spring element **296**.

The flow path between PRV inlet **224** and PRV outlet **226** may include a flow area **222** within PRV **200**, with a geometry of flow area **222** dependent in part on a restricting element **204**. Restricting element **204** may comprise, for example, valve stem **218** mechanically coupled to valve disc **216**. Flow area **222** is defined by any suitable structures. In some examples, as shown in FIG. 2, flow area **222** is at least partially bounded by valve disc **216** and valve seat **220**. PRV

**200** is configured to allow for restricting element **204** to translate and alter flow area **222**. The alteration of flow area **222** may alter a pressure drop a fluid flow experiences between PRV inlet **224** and PRV outlet **226**, allowing for the regulation of a fluid flow between PRV inlet **224** and PRV outlet **226**.

PRV **200** further includes a sensing element **206**. Sensing element **206** is configured to influence the translation of restricting element **204**. For example, sensing element **206** may be mechanically coupled to restricting element **204**. Sensing element **206** includes a first side **240** and a second side **242**, and may be configured such that sensing element **206** experiences motion based on a differential pressure between first side **240** and second side **242**. The differential pressure may arise from a first pressure acting on first side **240** and a second side acting on second side **242**. For example, sensing element **206** may comprise a diaphragm or a piston having a first side and a second side. Sensing element **206** may define a perimeter **244** surrounding a portion of sensing element **206**. Sensing element **206** may be mechanically coupled and/or fixably attached to housing **230** of PRV **200** around all or some part of perimeter **244**. For example, sensing element **206** may be a particular diaphragm defining a perimeter **244** and fixably attached around the entirety of perimeter **244**. Sensing element may be a piston with perimeter **244** slidably translatable over some portion of housing **230**.

In some examples, sensing element **206** provides a substantially pressure-tight barrier between pressure chamber **202** of PRV **200** and some other portion of PRV **200**, where the other portion of PRV **200** is configured to experience a pressure dependent on a fluid flow through PRV **200**. For example, sensing element **206** may provide a provide a substantially pressure-tight barrier between pressure chamber **202** and some portion of PRV **200** between and including flow area **222** and PRV outlet **226**. Sensing element **206** may be configured to respond (e.g., by deflection of the diaphragm, or translation of the piston) based on a differential pressure between the pressure chamber and the portion of PRV **200**.

As discussed, the differential pressure across sensing element **206** may arise from a first pressure acting on first side **240** and a second pressure acting on second side **242**. In some examples, the first pressure acting on first side **240** of sensing element **206** may arise from a gas pressure within a pressure chamber **202** of PRV **200** and the second pressure acting on second side **242** of sensing element **206** may arise from a fluid flow through PRV **200**. For example, the second pressure may arise from fluid communication with one or more flow sections of a fluid flow between and including flow area **222** and PRV outlet **226**, where the one or more flow sections are separated from pressure chamber **202** by the substantially pressure-tight barrier provided by sensing element **206**. The second pressure may arise from flow sections which encounter second side **242** of sensing element **206**, as well as from flow sections which encounter valve disc **216**. Hence, in some examples, the differential pressure experienced across sensing element **206** is dependent on both a gas pressure within pressure chamber **202** and the fluid flow pressure at one or more flow sections of a fluid flowing from flow area **222** in the direction of PRV outlet **226**.

In some examples, PRV **200** is configured to adjust flow area **222** (in response to changes in a downstream pressure. Adjusting flow area **222** adjusts a pressure drop of fluid flow through flow area **222**. "Adjustment" to flow area **222** can refer to the adjustment to a size of flow area, such as an

adjustment to a volume of flow area **222**. The downstream pressure may be a pressure at PRV outlet **226**, or some other flow section downstream of flow area **222**. For example, with a substantially constant gas pressure in pressure chamber **202**, an increase in the downstream pressure may increase the second pressure acting on second side **242**, and cause sensing element **206** to reposition restricting element **204** in a manner that increases a pressure drop of a fluid as it flows through flow area **222** (e.g., sensing element **206** may reposition restricting element **204** in a closing direction such as D2 to decrease flow area **222**). The increased pressure loss through flow area **222** may cause a decrease in the downstream pressure at, for example, PRV outlet **226**, or some other flow section downstream of flow area **222**.

Alternatively, with a substantially constant gas pressure in pressure chamber **202**, a decrease in downstream pressure may decrease the second pressure acting on second side **242**, and cause sensing element **206** to reposition restricting element **204** in a manner that decreases a pressure drop of a fluid as it flows through flow area **222** (e.g., sensing element **206** may reposition restricting element **204** in an opening direction such as D1 to increase flow area **222**). The decreased pressure loss through flow area **222** may cause an increase in the downstream pressure at, for example, PRV outlet **226**, or some other flow section downstream of flow area **222**. Hence, the differential pressure experienced across sensing element **206**, and the subsequent response of PRV **200**, may be dependent on both a gas pressure within pressure chamber **202** and a fluid flow pressure at one or more flow sections downstream of flow area **222**.

By adjusting the gas pressure in pressure chamber **202** (i.e., the first pressure acting on first side **240** of sensing element **206**), PRV **200** may be configured such that sensing element **206** operates around a specific pressure setpoint. Increases in downstream pressure above the setpoint may cause sensing element **206** to translate restricting element **204** to decrease flow area **222** and decrease the downstream pressure. Decreases in downstream pressure below the setpoint may cause sensing element **206** to translate restricting element **204** to increase flow area **222** and increase the downstream pressure.

In this manner PRV **200** may regulate a flow from PRV inlet **224** to PRV outlet **226** to substantially maintain a fluid pressure downstream of flow area **222**, based on a differential pressure across sensing element **206**. For example, PRV **200** may maintain the downstream fluid pressure within at least 1% to about 30% of a setpoint pressure, such as at within about 1%, 5%, 10%, 20%, or 30% of the setpoint pressure.

As discussed, the differential pressure across sensing element **206** may arise from the first pressure acting on first side **240** (exerted at least in part by the gas pressure in pressure chamber **202**) and the second pressure acting on second side **242** (exerted at least in part by one or more flow sections of the fluid flow between PRV inlet **224** and PRV outlet **226**). Consequently, PRV **200** may be configured such that the fluid pressure substantially maintained at PRV outlet **226** can be adjusted by adjusting the gas pressure in pressure chamber **202**.

Pressure chamber **202** is defined or surrounded at least in part by housing **230** of PRV **200**, which can be formed from any suitable material, such as, but not limited to metals, polymers, ceramics, or combinations thereof. Pressure chamber **202** may comprise a volume surrounded by a substantially gas-tight (e.g., gas-tight or gas-tight to the extent permitted by manufacturing tolerances) boundary, with the volume in fluid communication with sensing ele-

ment **206**. The volume may have any suitable shape. In examples, the volume may be partially enclosed by a dome-shaped boundary, such as boundary **265**. Exterior **276** of housing **230** may be fluidly isolated from the gas-tight boundary of pressure chamber **202**.

Pressure chamber **202** is configured to be isolated from flow pressures experienced by components of PRV **200** which fluidly communicate with a fluid flow from PRV inlet **224** to PRV outlet **226**, in order to substantially maintain the gas pressure of a gas present within pressure chamber **202**. For example, when pressure chamber **202** holds a gas at a gas pressure, pressure chamber **202** may be isolated from, for example, flow pressures at PRV inlet **224** and PRV outlet **226**, such that pressure chamber **202** may substantially maintain the gas pressure despite variations in the flow pressure. In examples, pressure chamber **202** may be isolated from valve inlet **224**, flow area **222**, valve seat **220**, restricting element **204**, second side **242** of sensing element **206**, and PRV outlet **226**. Sensing element **206** may be configured to such that first side **240** provides some portion of the pressure isolation between pressure chamber **202** and valve inlet **224**, flow area **222**, valve seat **220**, restricting element **204**, second side **242** of sensing element **206**, and PRV outlet **226**.

PRV **200** is configured to establish a pressure setpoint using a gas pressure in a pressure chamber such as pressure chamber **202**. PRV **200** includes a controller **214** configured to control (e.g., by increasing or decreasing) the gas pressure within pressure chamber **202**, in order to adjust the pressure setpoint within a system supplied by PRV **200**. Such adjustments may be beneficial in a variety of circumstances. For example, PRV **200** may be configured to receive a fluid from a main branch at PRV inlet **224** and provide the fluid at a lower pressure to a secondary branch via PRV outlet **226**. The primary branch may be, for example, a municipal water supply, while the secondary branch might comprise a portion of a water distribution system in a residence. It might be advantageous to vary the pressure setpoint of the residential distribution system based on, for example, a time of day. Controller **214** might act to increase the pressure setpoint during daylight hours as opposed to night time hours, if higher water demand is more likely to be initiated during the daylight hours due to occupant activity. Increasing the pressure setpoint during anticipated periods of higher demand might serve to lessen the impact of pressure transients throughout the system when multiple water loads are initiated substantially simultaneously. In an industrial type setting, controller **214** might act to establish certain pressure setpoints at certain times of day based on fluid loads anticipated from scheduled operations, historical data, or other indicators of anticipated demand.

Varying the pressure setpoint based on the actuation of specific fluid loads and the anticipated demand of the load may also provide one or more advantages in some examples. For example, controller **214** might receive an indication that a specific fluid load has been initiated and establish the pressure setpoint based on that specific fluid load. For example, in a residential water system, controller **214** might establish a first setpoint when a potentially higher demand load such as a washing machine is initiated, and establish a second setpoint when a potentially lower demand load such as a kitchen faucet is initiated. In an industrial setting, controller **214** might establish pressure setpoints based on the initiation of one or more specific processes. Matching a fluid pressure to a specific demand may generate a degree of fluid conservation by somewhat avoiding situations where



fluid may be supplied to the specific load at a greater rate than the specific load requires.

Controller **214** is configured to establish a pressure set-point by increasing or decreasing a gas pressure in pressure chamber **202**. In some examples, PRV **200** comprises a compressor **208** configured to increase a gas pressure inside pressure chamber **202**, e.g., by introducing gas into pressure chamber **202**, and a vent valve **210** configured to decrease a gas pressure inside pressure chamber, e.g., by defining a pathway through which gas may leave pressure chamber **202**.

In some examples, controller **214** communicates with compressor **208** and directs (e.g., controls directly or indirectly) compressor **208** to increase the gas pressure in pressure chamber **202** in order to adjust the pressure set-point. Controller **214** may communicate with compressor **208** using, for example, compressor communication link **246**. Controller **214** may communicate with vent valve **210** and direct vent valve **210** to establish a valve position that decreases the gas pressure in pressure chamber **202** in order to adjust the pressure setpoint. Controller **214** may communicate with vent valve **210** using, for example, vent valve communication link **248**. Compressor communication link **246** and/or vent valve communication link **248** may be hard-line and/or wireless communications links. In some examples, vent valve communication link **248** and/or compressor communication link **246** may comprise some portion of controller **214**. In some examples, vent valve communication link **248** and/or compressor communication link **246** comprise a wired connection, a wireless Internet connection, a direct wireless connection such as wireless LAN, Bluetooth™, Wi-Fi™, and/or an infrared connection. Vent valve communication link **248** and/or compressor communication link **246** may utilize any wireless or remote communication protocol.

Controller **214** includes controller circuitry and can comprise any suitable arrangement of hardware, software, firmware, or any combination thereof, to perform the techniques attributed to controller **214** herein. For example, controller **214** may include any one or more microprocessors, digital signal processors (DSPs), application specific integrated circuits (ASICs), field programmable gate arrays (FPGAs), or any other equivalent integrated or discrete logic circuitry, as well as any combinations of such components.

Compressor **208** is configured to establish fluid communication with pressure chamber **202**. For example, in the example shown in FIG. 2, compressor **208** is configured to establish fluid communication with pressure chamber **202** through compressor conduit **228** of housing **230** and/or boundary **265**. Compressor **208** is configured to draw a gas through compressor inlet **232**, increase a pressure of the gas, and provide the gas via compressor conduit **228** to pressure chamber **202**. Compressor **208** may be a centrifugal compressor, a positive displacement compressor, or any other type of device which is configured to draw gas at an inlet and provide a higher pressure flow of the gas at an outlet. Compressor **208** may be configured to operate using an alternating current (AC) input power, direct current (DC) input power, or a combination. In examples, compressor **208** comprise a Brushless DC Motor (BLDC). In some examples, compressor **208** may include processing circuitry configured to control components of compressor **208** in response to a received electrical or electronic communication. The processing circuitry can be provided by controller **214** or may be separate from controller **214**. Compressor **208** may be configured to provide communications to other devices in data communication with compressor **208**. In

examples, compressor **208** may be configured to establish a pressure barrier between pressure chamber **202** and compressor inlet **232**.

In the example shown in FIG. 2, PRV **200** includes a vent valve **210** configured to establish fluid communication with pressure chamber **202**. For example, at FIG. 2, vent valve **210** may establish fluid communication with pressure chamber **202** through vent conduit **234** of housing **230**. Vent valve **210** comprises vent valve outlet **236** and is configured to provide fluid communication between pressure chamber **202** and vent valve outlet **236**. Vent valve **210** may act to provide a fluid flow path to reduce the pressure  $P_c$  of pressure chamber **202**. In some examples, controller **214** is configured to communicate with vent valve **210** and control the operations of vent valve **210**. For example, controller **214** may communicate with vent valve **210** via vent valve communication link **248**.

In examples, vent valve **210** is configured to establish a pressure barrier between pressure chamber **202** and vent valve outlet **236**. Vent valve **210** may be a globe valve, a gate valve, a spool valve, a poppet valve, or any other type of valve mechanism which may be configured to control a flow path from an inlet to an outlet. In some examples, vent valve **210** may be a remotely actuated valve. In some examples, vent valve **210** comprises a solenoid actuator configured to influence the position of a plunger mechanically coupled to a flow restricting element, such as a valve disc. Vent valve **210** may be configured to translate a flow restricting element based on a supply of a control fluid. For example, vent valve **210** may be a hydraulically or pneumatically operated valve. Vent valve **210** may include processing circuitry configured to control components of vent valve **210** in response to a received electrical or electronic communication. The processing circuitry can be provided by controller **214** or may be separate from controller **214**. Vent valve **210** may be configured to provide communications to other devices in data communication with compressor vent valve **210**. Controller **214** may direct vent valve **210** to fully or partially open and provide fluid communication between pressure chamber **202** and vent valve outlet **236**, and may direct vent valve **210** to fully or partially close and cease or reduce a fluid communication between pressure chamber **202** and vent valve outlet **236**.

To control the pressure within pressure chamber **202**, controller **214** may, at various times, conduct one or more of: direct compressor **208** to commence charging a gas into pressure chamber **202**, direct compressor **208** to cease charging the gas into pressure chamber **202**, direct vent valve **210** to fully or partially open and provide fluid communication between pressure chamber **202** and vent valve outlet **236**, and direct vent valve **210** to fully or partially close and cease or reduce a fluid communication between pressure chamber **202** and vent valve outlet **236**. As discussed below, the action selected by controller **214** for compressor **208** and vent valve **210** may depend on whether controller **214** is increasing or decreasing pressure within pressure chamber **202**.

PRV **200** further includes a pressure sensor **212** configured to generate a signal indicative of a pressure. For example, as depicted at FIG. 2, pressure sensor **212** may be configured to generate a signal indicative of a pressure at PRV outlet **226**, and/or indicative of a pressure downstream of flow area **222**. Pressure sensor **212** may generate a signal as a function of a pressure imposed on some portion of pressure sensor **212**. Pressure sensor **212** may be configured to use any type of force collector to sense the outlet pressure, including, for example, diaphragms, pistons, bourdon tubes,

bellows, or some other collector. Pressure sensor **212** may transduce the pressure into an electrical signal using, for example, piezoresistive strain gauges, capacitors, electromagnets, optical fibers, potentiometric wipers, or other devices. Pressure sensor **212** may be configured to sense an absolute pressure or a gauge pressure. The signal indicative of the pressure generated by pressure sensor **212** may be an analog electrical signal or a digital signal. Pressure sensor **212** may include processing circuitry configured to interpret a response of the force collector and generate the signal indicative of the pressure, and/or controller **214** may include processing circuitry configured to interpret a response of the force collector and generate the signal indicative of the pressure. Pressure sensor **212** may be configured to provide communicate the signal indicative of the pressure to other devices in data communication with pressure sensor **212**.

Controller **214** is configured to receive the signal indicative of the pressure from pressure sensor **212**. Controller **214** may receive the signal indicative of the pressure via, for example, sensor communication link **238** between controller **214** and pressure sensor **212**. Controller **214** is configured to compare the signal indicative of the pressure received from pressure sensor **212** with a pressure setpoint. The pressure setpoint may be stored in a memory of controller **214** or of another device of system **200** or communicatively coupled to controller **214**. The memory may include any volatile or non-volatile media, such as a random access memory (RAM), read only memory (ROM), non-volatile RAM (NVRAM), electrically erasable programmable ROM (EEPROM), flash memory, and the like. In some examples, the memory may be internal to controller **214**. In addition, in some examples, the memory or another memory may also store executable instructions for causing the one or more controllers described herein to perform the actions attributed to them.

Sensor communication link **238** may be hard-line and/or wireless communications link. Sensor communication link **238** may comprise some portion of controller **214**. Sensor communication link **238** may comprise a wireless Internet connection, a direct wireless connection such as wireless LAN, Bluetooth™, Wi-Fi™, and/or an infrared connection. Sensor communication link **238** may utilize any wireless or remote communication protocol.

Based on the comparison of the indicative signal from pressure sensor **212** and the pressure setpoint, controller **214** is configured to increase or decrease a pressure in pressure chamber **202**. Controller **214** may direct compressor **208** to operate such that compressor **208** draws a gas such as air into compressor inlet **232** and directs the gas into pressure chamber **202**, increasing the gas pressure of pressure chamber **202**. Controller **214** may control vent valve **210** and cause vent valve **210** to operate (e.g., to open) to provide fluid communication between pressure chamber **202** and an environment external to pressure chamber **202**, allowing pressure chamber **202** to vent and decrease the gas pressure of pressure chamber **202**.

Utilizing compressor **208** and vent valve **210**, controller **214** may be configured to increase or decrease the pressure of a secondary fluid branch in fluid communication with PRV outlet **226** of PRV **200**. For example, to increase or decrease a pressure in the secondary branch, controller **214** may receive or establish a revised pressure setpoint reflective of the new desired pressure. Based on a comparison of the revised setpoint and a signal indicative of the pressure provided by pressure sensor **212**, controller **214** may control compressor **208** and/or vent valve **210** to increase or decrease the pressure in pressure chamber **202**, causing PRV

**200** to establish a configuration causing an increase or decrease of the pressure at PRV outlet **226**, until a comparison of the revised setpoint and the signal indicative of the pressure provided by pressure sensor **212** indicates the pressure in pressure chamber **202** is satisfactory (e.g., within a predetermined range of the pressure setpoint, such as within 5% to 30%, such as within 5%, 10%, 20%, or 30% of the pressure setpoint in various examples).

In some examples, controller **214** may be provided with one or more pressure setpoints, e.g., a revised setpoint, via a communication from another device or via a user interface of controller **214**. The user interface can have any suitable configuration. For example, the user interface can include a button or keypad, a speaker configured to receive voice commands from a user, a display, such as a liquid crystal (LCD), light-emitting diode (LED), or organic light-emitting diode (OLED). In some examples the display may be a touch screen. The user interface is configured to receive user input, e.g., in the form of pressing one or more buttons on a keypad or via a touch screen, which may be user input selecting a desired pressure setpoint, for example. In some examples, the user interface is also configured to display information, such as one or more pressure setpoints (e.g., the current setpoint being used by controller **214** to control PRV **200** or one or more predetermined pressure setpoints from which the user can select to input a desired pressure setpoint).

In some examples, controller **214** may be configured to establish a desired setpoint based on a particular criteria. For example, controller **214** may be configured to establish a revised setpoint based on a time of day, a scheduled operation requiring or anticipated to require a particular fluid demand from PRV **200**, and/or the actuation of a specific fluid load supplied by PRV **200**.

In some examples, PRV **200** may be a reverse-seated valve. PRV **200** may be configured such that a movement of sensing element **206** in a direction toward valve seat **220** (e.g., in the direction D1) causes restricting element **204** to translate and increase flow area **222**. The movement of sensing element **206** toward valve seat **220** may be caused by a decrease in the pressure of a fluid section within PRV **200**. The fluid section may be a fluid section downstream of flow area **222**. The movement of sensing element **206** toward valve seat **220** may be caused by an increase in the pressure of a gas within pressure chamber **202**. Controller **214** may increase the pressure of the gas within pressure chamber **202** causing sensing element to move in a direction toward valve seat **220** (e.g., in the direction D1) and increase flow area **222**. The increase in flow area **222** may reduce the pressure drop of a fluid flowing through flow area **222**, increasing the pressure at PRV outlet **226**.

PRV **200** may be configured such that a movement of sensing element **206** in a direction away from valve seat **220** (e.g., in the direction D2) causes restricting element **204** to translate and decrease flow area **222**. The movement of sensing element **206** away from valve seat **220** may be caused by an increase in the pressure of a fluid section within PRV **200**. The fluid section may be a fluid section downstream of flow area **222**. The movement of sensing element **206** away from valve seat **220** may be caused by a decrease in the pressure of a gas within pressure chamber **202**. Controller **214** may decrease the pressure of the gas within pressure chamber **204** causing sensing element to move in a direction away from valve seat **220** (e.g., in the direction D2) and decrease flow area **222**. The decrease in flow area **222** may increase the pressure drop of a fluid flowing through flow area **222**, decreasing the pressure at PRV outlet **226**.

Restricting element **204** includes any suitable structure and is configured to translate in directions D1 and D2 using any suitable structure. In some examples, PRV **200** includes a spring element **296** configured to translate restricting element **204** to close PRV **200**. Spring element **296** may be configured to transmit a force to restricting element **204** in a direction which biases restricting element **204** to reduce (or eliminate in some examples) flow area **222**. The biasing force transmitted by spring element **296** to restricting element **204** may be in opposition to a force transmitted to restricting element **204**. Spring element **296** may be configured such that, if a force transmitted by sensing element **206** fails below a threshold, the biasing force transmitted by spring element **296** causes restricting element **204** to translate in a manner reducing or eliminating flow area **222** of PRV **200**. Spring element **296** may be configured to be in either tension or compression as it transmits the biasing force to restricting element **204**. For example, spring element **296** may be in compression and configured to transmit the biasing force to restricting **204** element by extending. As another example, spring element **296** may be in tension and configured to transmit the biasing force to restricting element **204** by contracting.

For example, FIG. 2 illustrates spring element **296** in compression between a section of PRV **200** and restricting element **204**. Spring element **296** is configured to transmit a force to restricting element **204** substantially in the direction D2, biasing restricting element **204** to translate in a manner reducing or eliminating flow area **222**. The biasing force transmitted by spring element **296** to restricting element **204** is in opposition to a force transmitted by sensing element **206** in the direction D1, which causes restricting element **204** to translate in a manner increasing flow area **222**. Spring element **296** is configured such that, if the force transmitted by sensing element **206** in the direction D1 fails below a threshold, the biasing force transmitted by spring element **296** causes restricting element **204** to translate in a manner reducing or eliminating flow area **222** of PRV **200**. For example, if controller **214** utilizes vent valve **210** to decrease the pressure in pressure chamber **202** as previously described, and the decreased pressure reduces the force transmitted by sensing element **206** in the direction D1 to below the threshold, the biasing force transmitted by spring element **296** may cause restricting element **204** to translate in a manner reducing or eliminating flow area **222** of PRV **200**.

In this manner, spring element **296** may act as a shut off mechanism for PRV **200**, acting to reduce or eliminate flow area **222** when controller **214** recognizes a condition under which PRV **200** should close and, in response, opens vent valve **210** to reduce the pressure in pressure chamber **202**. For example, in some examples, controller **214** may receive a leak signal from a leak detection system monitoring a fluid branch downstream of PRV **200**. Controller **214** may be configured such that, in response to receiving the leak signal, controller **214** causes vent valve **210** to open and reduce the pressure in pressure chamber **202** to a level where spring element **296** causes restricting element **204** to translate and close PRV **200**, thereby eliminating (to the extent possibly by the fluid seals of PRV **200**) fluid flow through PRV.

In examples, controller **214** may cause vent valve **210** to open and equalize the pressure in pressure chamber **202** with an atmosphere surrounding PRV **200** in response to receiving a leak signal from a leak detection system. For example, PRV **200** may be PRV **114** (FIG. 1). A leak detection system **182** (FIG. 1) might be configured to detect leakage from branch circuit **118** and controller **214** of PRV **114** may be

configured to receive a leak signal from leak detection system **182**. In response to the leak signal, controller **214** may reduce a pressure in pressure chamber **202**, so that spring element **296** closes PRV **114**.

In some examples, a PRV may be configured to function as a back-pressure regulator, to substantially maintain a pressure of fluid flow upstream of the flow area of the pressure regulating valve. For example, FIG. 3 illustrates an example PRV **300** configured to function as a back-pressure regulator. PRV **300** comprises PRV inlet **324** and PRV outlet **326** and is configured to provide a flow path for a fluid between PRV inlet **324** and PRV outlet **326**. PRV **300** may be configured to receive a fluid at PRV inlet **324** and regulate a fluid flow through flow area **322** and PRV outlet **326**, in order to substantially maintain a pressure of a flow section upstream of flow area **322**. For example, PRV **300** may be configured receive a fluid from main circuit **102** and regulate a fluid flow to fluid conduit **164** to substantially maintain a fluid pressure in main circuit **102** (FIG. 1). PRV **300** may be an example of PRV **150** described with reference to FIG. 1. PRV inlet **324**, flow area **322**, and PRV outlet **326** may be configured individually and relation to each other in the same manner as that discussed for the like-named components of PRV **200**.

As illustrated, PRV **300** further comprises restricting element **304**, valve disc **316**, valve stem **318**, valve seat **320**, sensing element **306** defining first side **340**, second side **342**, and perimeter **344**, pressure chamber **302**, housing **330** having a housing exterior **376** and a boundary **365**, controller **314**, pressure sensor **312**, compressor **308**, compressor conduit **328**, compressor inlet **332**, vent valve **310**, vent valve outlet **336**, vent conduit **334**, sensor communication link **338**, compressor communication link **346**, vent valve communication link **348**, and spring element **396**, which may be configured individually and relation to each other in the same manner as that discussed for the like-named components of PRV **200**.

For example, sensing element **306** is configured to influence the translation of restricting element **304**. For example, sensing element **306** may be mechanically coupled to restricting element **304**. Sensing element **306** includes first side **340** and a second side **342**, and may be configured such that sensing element **306** experiences motion based on a differential pressure between first side **340** and second side **342**. The differential pressure may arise from a first pressure acting on first side **340** and a second pressure acting on second side **342**. For example, sensing element **306** may comprise a diaphragm or a piston having a first side and a second side.

The first pressure acting on first side **340** of sensing element **306** may arise from a gas pressure within a pressure chamber **302**. The second pressure acting on second side **342** of sensing element **306** may arise from fluid communication with one or more fluid sections of a fluid between and including PRV inlet **324** and flow area **322**. Thus, the differential pressure experienced across sensing element **306** may be dependent on both a gas pressure within pressure chamber **302** and a fluid pressure between and including PRV inlet **324** and PRV outlet **326**.

PRV **300** may be configured to adjust flow area **322** in response to changes in an upstream pressure, such as a pressure at PRV inlet **324**, or some other fluid section upstream of flow area **322**. For example, with a substantially constant gas pressure (e.g., constant or nearly constant, such as less than or equal to a 5% change) in pressure chamber **302**, an increase in the upstream pressure may increase the second pressure acting on second side **342**, and cause

sensing element **306** to reposition restricting element **304** in a manner that increases flow area **322** (e.g., sensing element **306** may reposition restricting element **304** in an opening direction such as D2 to increase flow area **222**). The increased flow area **322** may cause a decrease in the upstream pressure at, for example, PRV inlet **324**, or some other fluid section upstream of flow area **322**.

Alternatively, with a substantially constant gas pressure in pressure chamber **302**, a decrease in upstream pressure may decrease the second pressure acting on second side **342**, and cause sensing element **306** to reposition restricting element **304** in a manner that decreases flow area **322** (e.g., sensing element **306** may reposition restricting element **304** in a closing direction such as D1 to decrease flow area **322**). The decreased flow area **322** may cause an increase in the upstream pressure at, for example, PRV inlet **324**, or some other flow section upstream of flow area **322**. In some examples, a decrease in upstream pressure may result in sensing element **306** acting to fully shut PRV **300**.

PRV **300** may be configured such that sensing element **306** operates around a specific pressure setpoint, based on the gas pressure in pressure chamber **302**. Increases in upstream pressure above the setpoint may cause sensing element **306** to translate restricting element **304** to increase flow area **322** (e.g., cause sensing element **306** to move in the direction D2) and decrease the upstream pressure. Decreases in upstream pressure below the setpoint may cause sensing element **306** to translate restricting element **304** to decrease flow area **322** (e.g., cause sensing element **306** to move in the direction D1) and increase the downstream pressure. In this manner PRV **300** may regulate a flow from PRV inlet **324** to PRV outlet **326** to substantially maintain a fluid pressure upstream of flow area **322**, based on a differential pressure across sensing element **306**. For example, PRV **300** may maintain the upstream pressure within 1% to 30% of a setpoint pressure, such as within 1%, 5%, 10%, 20%, or 30% of the setpoint pressure.

Controller **314** is configured to establish a pressure setpoint by increasing or decreasing a gas pressure in pressure chamber **302**. To control the pressure within pressure chamber **302**, controller **314** may, at various times, conduct one or more of: direct compressor **308** to commence charging a gas into pressure chamber **302**, direct compressor **308** to cease charging the gas into pressure chamber **302**, direct vent valve **310** to fully or partially open and provide fluid communication between pressure chamber **302** and vent valve outlet **336**, and direct vent valve **310** to fully or partially close and cease or reduce a fluid communication between pressure chamber **302** and vent valve outlet **336**. As discussed below, the action selected by controller **314** for compressor **308** and vent valve **310** may depend on whether controller **314** is increasing or decreasing pressure within pressure chamber **302**.

Controller **314** may communicate with compressor **308** via compressor communication link **346** and direct compressor **308** to increase the gas pressure in pressure chamber **302**. Controller **314** may communicate with vent valve **310** via vent valve communication link **348** and direct vent valve **310** to establish a valve position that decreases the gas pressure in pressure chamber **302**.

PRV **300** further includes a pressure sensor **312** configured to generate a signal indicative of a pressure. For example, as depicted at FIG. **3**, pressure sensor **312** may be configured to generate a signal indicative of a pressure at PRV inlet **324** and/or indicative of a pressure upstream of flow area **322**. Controller **314** is configured to receive the signal indicative of the pressure from pressure sensor **312**.

Controller **314** may receive the signal indicative of the pressure via, for example, sensor communication link **338** between controller **314** and pressure sensor **312**. Controller **314** may be configured to compare the signal indicative of the pressure received from pressure sensor **312** with a pressure setpoint. The pressure setpoint may be stored in a memory of controller **314** or a memory of another device. Based on the comparison of the indicative signal from pressure sensor **312** and the pressure setpoint, controller **314** may be configured to increase or decrease a pressure in pressure chamber **302** using compressor **308** (to increase the pressure) or vent valve **310** (to decrease the pressure), e.g., as discussed with respect to controller **214**, compressor **208**, and vent valve **210** of FIG. **2**.

Utilizing compressor **308** and vent valve **310**, controller **314** may be configured to increase or decrease the pressure of an upstream fluid branch in fluid communication with PRV inlet **324** of PRV **300**. For example, to increase or decrease a pressure in the upstream fluid branch, controller **314** may receive or establish a revised pressure setpoint reflective of the new desired pressure. Based on a comparison of the revised setpoint and a signal indicative of the pressure provided by pressure sensor **312**, controller **314** may control compressor **308** and/or vent valve **310** to increase or decrease the pressure in pressure chamber **302**, causing PRV **300** to establish a configuration causing an increase or decrease of the pressure at PRV inlet **324**, until a comparison of the revised setpoint and the signal indicative of the pressure provided by pressure sensor **312** indicates the pressure in pressure chamber **302** is satisfactory (e.g., within a predetermined range of the pressure setpoint, such as within 5% to 30%, such as within 5%, 10%, 20%, or 30% of the pressure setpoint in various examples).

In some examples, PRV **300** may be a normally-seated valve. PRV **300** may be configured such that a movement of sensing element **306** in a direction away from valve seat **320** (e.g., in the direction D2) causes restricting element **304** to translate and increase flow area **322**. The movement of sensing element **306** away from valve seat **320** may be caused by a decrease in the pressure of a fluid section within PRV **300**. The fluid section may be a fluid section upstream of flow area **322**. The movement of sensing element **306** away from valve seat **320** may be caused by a decrease in the pressure of a gas within pressure chamber **302**. Controller **314** may decrease the pressure of the gas within pressure chamber **304** causing sensing element **306** to move in a direction away from valve seat **320** (e.g., in the direction D2) and increase flow area **322**. The increase in flow area **322** may reduce the pressure drop of a fluid flowing through flow area **322** (or initiate a fluid flow through flow area **322**), decreasing the pressure at PRV inlet **324**.

PRV **300** may be configured such that a movement of sensing element **306** in a direction toward valve seat **320** (e.g., in the direction D1) causes restricting element **304** to translate and decrease flow area **322**. The movement of sensing element **304** toward valve seat **320** may be caused by a decrease in the pressure of a fluid section within PRV **300**. The fluid section may be a fluid section upstream of flow area **322**. The movement of sensing element **304** toward from valve seat **320** may be caused by an increase in the pressure of a gas within pressure chamber **302**. Controller **314** may increase the pressure of the gas within pressure chamber **302** causing sensing element **306** to move in a direction toward valve seat **320** (e.g., in the direction D1) and decrease flow area **322**. The decrease in flow area **322** may increase the pressure drop of a fluid flowing through

flow area **322** (or cease a fluid flow through flow area **322**), increasing the pressure at PRV inlet **324**.

Restricting element **304** includes any suitable structure and is configured to translate in directions D1 and D2 using any suitable structure. In some examples, PRV **300** may include spring element **396**. Spring element **396** may be configured to transmit a force to restricting element **304** substantially in the direction D1, biasing restricting element **304** to translate in a manner reducing or eliminating flow area **322**. Spring element **396** may act as a shut off mechanism for PRV **300**, acting to reduce or eliminate flow area **322** when controller **314** recognizes a condition under which PRV **300** should close and, in response, opens vent valve **310** to reduce the pressure in pressure chamber **302**. For example, in some examples, controller **314** is configured to receive a leak signal from a leak detection system monitoring a fluid branch upstream of PRV **300**, and, in response to receiving the leak signal, controller **314** opens vent valve **310** and reduces the pressure in pressure chamber **302** to a level where spring element **396** causes restricting element **304** to translate and close PRV **300**.

In some examples, controller **214** (FIG. 2) and/or controller **314** (FIG. 3) may comprise a Proportional-Integral-Derivative (PID) controller. The PID controller may receive a pressure signal from a pressure sensor such as pressure sensor **212** and/or pressure sensor **312** as a process variable, and may periodically determine an error based on a difference between a pressure setpoint and a pressure indicated by the pressure signal. The PID controller may produce a control signal based on the error. Controller **214** may control compressor **208** and/or vent valve **210** based on the control signal. Controller **314** may control compressor **308** and/or vent valve **310** based on the control signal.

The PID controller may produce the control signal using a proportional term (P) proportional to the value of the error. The PID may produce the control signal using an integral term (I) based on past values of the error integrated over time. The PID may produce the control signal using a derivative term (D) based on a rate of change of the error. The PID controller may determine the control signal based on a weighted sum of the P, I, and/or D terms. The PID controller may be a digital PID controller which converts an analog pressure signal from a sensor to a digital signal using an analog-to-digital (A/D) convertor. The PID controller may comprise one or more analog components such as one or more operational amplifiers.

The controller comprising the pressure regulating valve may be configured to receive a communication signal from, for example, one or more fluid loads, and determine a pressure setpoint based on the communication signal. FIG. 4 is a conceptual diagram of an example PRV **400** comprising at least a vent valve **408**, a compressor **410**, a controller **414**, and a pressure sensor **416**. Components of PRV **400** may be configured individually and relation to each other in the same manner as that discussed for the like-named components of PRV **200**.

A fluid circuit **498** is configured to provide fluid to fluid load **488** and fluid load **490**. Fluid load **488** and fluid load **490** may be parallel fluid loads. Each of fluid load **488** and fluid load **490** are configured to communicate with controller **414** when the respective loads are actuated. Fluid load **488** may communicate with controller **414** via communication link **482**. Fluid load **490** may communicate with controller **414** via communication link **484**. Communication links **482**, **484** may be hard-line and/or wireless communications links, e.g., any of the example communication links described above.

PRV **400** is configured to receive a fluid from fluid circuit **402** and provide fluid to fluid circuit **498** at a pressure based on a pressure setpoint. The pressure setpoint may be based on the actuation of fluid load **488** and/or fluid load **490**. For example, controller **414** may be configured to receive a first signal from fluid load **488** via communication link **482** and establish a first pressure setpoint in response to the first signal. Controller **414** may direct compressor **410** to increase pressure in a pressure chamber (not shown) of PRV **400** and/or direct vent valve **408** to decrease pressure in the pressure chamber of PRV **400**, until pressure sensor **416** indicates the first setpoint has been established in fluid circuit **498** (e.g., the pressure in fluid circuit **498** is within a predetermined range of the first setpoint, such as equal to or within 1% to 30% of the first setpoint).

Controller **414** may be configured to receive a second signal from fluid load **490** via communication link **484** and establish a second pressure setpoint in response to the second signal. The second setpoint may be different (e.g. higher or lower) than the first setpoint. Controller **414** may direct compressor **410** to increase pressure in a pressure chamber (not shown) of PRV **400** and/or direct vent valve **408** to decrease pressure in the pressure chamber of PRV **400**, until pressure sensor **416** indicates the second setpoint has been established in fluid circuit **498** (e.g., the pressure in fluid circuit **498** is within a predetermined range of the second setpoint, such as equal to or within 1% to 30% of the second setpoint).

In some examples, controller **414** may also be configured to establish a third pressure setpoint based on receipt of both the first signal from fluid load **488** and the second signal from fluid load **490**. Controller **414** may be configured to receive signals and establish a pressure setpoint for any number of fluid loads, and establish a pressure setpoint for any combination of fluid loads.

For example, fluid circuit **402** might be a municipal water main and fluid circuit **498** might be a residential water main. PRV **400** may be configured to receive a higher pressure fluid from fluid circuit **402** and provide a lower pressure fluid to fluid circuit **498**. Fluid load **488** and fluid load **490** may be residential fluid loads. For example, fluid load **488** might be kitchen faucet while fluid load **490** might be a dishwasher. It may be advantageous for PRV **400** to substantially maintain fluid circuit **498** at different pressures depending on which or fluid loads **488**, **490** are in operation. Controller **414** may be configured to substantially maintain a first pressure in fluid circuit **498** when fluid load **490** (e.g., dishwasher) is actuated (e.g., operating and using water), based on the anticipated water demand of fluid load **490**. Controller **414** may be configured to substantially maintain a second pressure less than the first pressure when fluid load **488** (e.g., kitchen faucet) is actuated, in order to reduce over-supply of water for the generally lower water demand of tasks typically performed with fluid load **488**. It may be advantageous to configure controller **414** to substantially maintain a third pressure greater than the first pressure and the second pressure when both fluid load **488** and fluid load **490** are actuated, in order to provide a sufficient flow of fluid through the residential piping when both loads are operating simultaneously.

PRV **400** may also be configured to operate as a back-pressure regulator substantially maintaining a pressure in fluid circuit **498** and providing a fluid flow from fluid circuit **498** to fluid circuit **402** to substantially maintain the pressure. Fluid load **488** and fluid load **490** may require differing pressure setpoints for fluid circuit **498**. For example, fluid load **488** may be a first bank of flow spray nozzles operating

effectively at a first pressure while fluid load **490** may be a second bank of spray nozzles operating effectively at a second pressure different from the first pressure. Controller **414** may be configured to receive a signal from each of fluid load **488** and fluid load **490**, and establish a pressure setpoint for fluid circuit **498** depending on whether the first pressure or second pressure is desired.

The compressor, vent valve, sensor, and controller of PRV **400** may be configured individually and relation to each other in the same manner as that discussed for the like-named components of PRV **200** and/or PRV **300**. PRV **400** may also comprise a PRV inlet, a flow area, a PRV outlet, a restricting element, a valve disc, a valve stem, a valve seat, a sensing element, a first side, a second side, a perimeter, a pressure chamber, a housing, a housing exterior, a boundary, a compressor conduit, a compressor inlet, a vent valve outlet, a vent conduit, a sensor communication link, a compressor communication link, a vent valve communication link, and a spring element, which may be configured individually and relation to each other in the same manner as that discussed for the like-named components of PRV **200** and/or PRV **300**.

A compressor of a PRV may comprise a compressor housing mechanically coupled to or integral with the housing exterior of the PRV. FIG. **5** illustrates a portion of an example PRV **500** comprising an example compressor **508**. Compressor **508** includes a compressing element **592** in fluid communication with compressor inlet **532** and compressor outlet **573**. Compressing element **592** is configured to establish a suction at compressor inlet **532** and provide a discharge at compressor outlet **573**. Compressing element **592** may comprise, for example, an impeller or a piston.

Compressor **508** includes compressor housing **571** at least partially surrounding compressing element **592**. Compressor housing **571** may be mechanically coupled to or integral with housing exterior **576** of PRV **500**. Compressor outlet **573** may be in fluid communication with compressor conduit **528**, which is in fluid communication with pressure chamber **502**. For example, compressor conduit **528** may extend through housing **530**, housing exterior **576**, and/or boundary **565** of pressure chamber **502**.

In some examples, a vent valve of a PRV may be mechanically coupled to or integral with the exterior housing of the PRV. FIG. **5** illustrates an example vent valve **510** mechanically coupled to or integral with housing exterior **576**. Vent valve inlet **574** of vent valve **510** is in fluid communication with vent conduit **534**, which is in fluid communication with pressure chamber **502**. For example, vent conduit **534** may extend through housing **530**, housing exterior **576**, and/or boundary **565**. Vent valve **510** may comprise one or more valve components configured to fluidly isolate vent valve inlet **574** and vent valve outlet **536**.

In some examples, a controller of a PRV may be positioned outside the housing of the PRV or may be mechanically coupled to or integral with the housing exterior of the pressure regulating valve. FIG. **5** illustrates an example controller **514** at least partially surrounded by controller housing **572**, with controller housing **572** mechanically coupled to or integral with housing exterior **576**. In some examples, a single housing (not shown) may cover one or more of controller **514**, compressor **508**, and vent valve **510**, in any combination. The single housing may be mechanically coupled to or integral with housing exterior **576**. Controller housing **572** is configured to protect circuitry of controller **514** from environmental contaminants.

Pressure chamber **502**, housing **530**, housing exterior **576**, boundary **565**, controller **514**, compressor **508**, compressor

conduit **528**, compressor inlet **532**, vent valve **510**, vent valve inlet **574**, vent valve outlet **536**, and vent conduit **534** may be configured individually and relation to each other in the same manner as that discussed for the like-named components of PRV **200**, PRV **300**, and/or PRV **400**. In some examples, PRV **500** may also comprise a PRV inlet, a flow area, a PRV outlet, a restricting element, a valve disc, a valve stem, a valve seat, a sensing element, a first side, a second side, a perimeter, a pressure sensor, a sensor communication link, a compressor communication link, a vent valve communication link, and a spring element, which may be configured individually and relation to each other in the same manner as that discussed for the like-named components of PRV **200**, PRV **300**, and/or PRV **400**.

In some examples, a compressor of a PRV may be internal to a pressure chamber of the PRV, the pressure chamber being the same pressure chamber that the controller can introduce gases into. FIG. **6** illustrates a portion of an example PRV **600** comprising compressor **608**, which is an example compressor that is substantially within pressure chamber **602** and is likewise surrounded by housing **630**. Compressor **608** can be configured like the example compressors described with reference to FIGS. **2-5**, but is positioned substantially within pressure chamber **602**. For example, compressor **608** may be surrounded by the volume within the gas-tight boundary of pressure chamber **602**. Compressor inlet **632** of compressor **608** is fluidically connected to compressor outlet **673** via compressor conduit **628**, which extends through housing **630**, housing exterior **676**, and/or boundary **665**. Compressor outlet **673** is in fluid communication with pressure chamber **602**. Compressor **608** may comprise compressing element **692** in fluid communication with compressor inlet **632** and compressor outlet **673**. Compressing element **692** may be surrounded by pressure chamber **602** such that compressor inlet **632** is in fluid communication with compressor conduit **628** extending through housing **630**, housing exterior **676**, and/or boundary **665**, and compressor outlet **673** is in fluid communication with the volume within the gas-tight boundary of pressure chamber **602**.

In some examples, a vent valve of a PRV can be internal to a pressure chamber of the PRV, the pressure chamber being the same pressure chamber from which the vent valve releases gases. FIG. **6** illustrates an example of a vent valve **610** that is substantially within pressure chamber **602** and surrounded by housing **630**. Vent valve **610** can be configured like the example vent valves described with reference to FIGS. **2-5**, but is positioned substantially within pressure chamber **602**. Vent valve outlet **636** of vent valve **610** is in fluid communication with vent inlet **674** via vent conduit **634**, which may extend through housing **630**, housing exterior **676**, and/or boundary **665**. Vent valve inlet **674** may be in fluid communication with pressure chamber **602**. Vent valve **610** may comprise one or more valve components configured to fluidly isolate vent valve inlet **674** and vent valve outlet **636**. Vent valve **610** may be surrounded by pressure chamber **602** such that vent valve outlet **636** is in fluid communication with vent conduit **634** extending through housing **630** and/or boundary **665**, and vent valve inlet **674** is in fluid communication with the volume within the gas-tight boundary of pressure chamber **602**.

In some examples, a controller of a PRV can be internal to a pressure chamber of the PRV, the pressure chamber being a chamber for which the controller controls the pressure. FIG. **6** illustrates an example controller **614** that is substantially within pressure chamber **602** and surrounded by housing **630**. Controller **614** can be configured like the

example controllers described with reference to FIGS. 2-5, but is positioned substantially within pressure chamber 602. In some examples, a hard-line connection 680 may extend through housing 630, exterior housing 676, and/or boundary 665. Hard-line connection 680 may be in electrical communication with controller 614. Hard-line connection 680 may be configured to provide data communications and/or electrical power to controller 614.

A hatch 675 may be configured to allow access into pressure chamber 602 through housing 630, housing exterior 676, and/or boundary 665. Hatch 675 may be configured to have an open position providing access to the volume within pressure chamber 602 and have a closed position, where hatch 675 forms a portion of the gas-tight boundary around pressure chamber 602 when in the closed position.

Pressure chamber 602, housing 630, housing exterior 676, boundary 665, controller 614, compressor 608, compressor element 692, compressor conduit 628, compressor inlet 632, compressor outlet 673, vent valve 610, vent valve outlet 636, vent valve inlet 674, and vent conduit 634 may be configured individually and relation to each other in the same manner as that discussed for the like-named components of PRV 200, PRV 300, PRV 400, and/or PRV 500. In some examples, PRV 600 may also comprise a PRV inlet, a flow area, a PRV outlet, a restricting element, a valve disc, a valve stem, a valve seat, a sensing element, a first side, a second side, a perimeter, a sensor, a sensor communication link, a compressor communication link, a vent valve communication link, and a spring element, which may be configured individually and relation to each other in the same manner as that discussed for the like-named components of PRV 200, PRV 300, PRV 400 and/or PRV 500.

In examples, a vent valve and a compressor of a PRV may both be in fluid communication with a chamber conduit extending through the housing, housing exterior, and/or boundary of the pressure chamber. For example, FIG. 7 illustrates a portion of an example PRV 700 comprising vent valve 710, compressor 708, and controller 714. Vent valve 710, compressor 708, and controller 714 are surrounded by a control housing 794. Control housing 794 may be mechanically coupled to or integral with housing exterior 776.

Vent valve 710 comprises vent valve outlet 736 and vent valve inlet 774. Vent valve 710 may comprise one or more valve components configured to fluidly isolate vent valve inlet 774 and vent valve outlet 736. Vent valve inlet 774 may be configured to be in fluid communication with chamber conduit 793. Chamber conduit 793 may extend through housing 730, housing exterior 776, and/or boundary 765. Compressor 708 may comprise compressing element 792 in fluid communication with compressor inlet 732 and compressor outlet 773. Compressor outlet 573 may be configured to be in fluid communication with chamber conduit 593.

Pressure chamber 702, housing 730, housing exterior 776, boundary 765, controller 714, compressor 708, compressor inlet 732, compressor element 792, compressor outlet 773, vent valve 710, vent valve outlet 736, and vent valve inlet 774 may be configured individually and relation to each other in the same manner as that discussed for the like-named components of PRV 200, PRV 300, PRV 400, PRV 500, and/or PRV 600. In some examples, PRV 700 may also comprise a PRV inlet, a flow area, a PRV outlet, a restricting element, a valve disc, a valve stem, a valve seat, a sensing element, a first side, a second side, a perimeter, a pressure sensor, a sensor communication link, a compressor communication link, a vent valve communication link, a spring

element, a hatch, and a hard-line connection, which may be configured individually and relation to each other in the same manner as that discussed for the like-named components of PRV 200, PRV 300, PRV 400, PRV 500, and/or PRV 600.

FIG. 8 illustrates a flow diagram of an example technique for regulating a pressure. Although the technique is described with reference to PRV 200 of FIG. 2, in other examples, the technique may be used with another PRV. In addition, controller 214 of PRV alone or in combination with controllers of other devices can perform any part of the technique shown in FIG. 8.

Controller 214 receives a pressure signal indicative of a pressure (802). In some examples, the pressure signal may be indicative of a pressure at valve outlet 226 of PRV 200. In some examples, pressure sensor 212 generates the pressure signal indicative of the pressure and transmits the signal to controller 214 using any suitable communication link. Controller 214 determines a pressure offset between the pressure indicated by the pressure signal and a pressure setpoint (804). For example, controller 214 can determine the pressure based on a signal characteristic of the pressure signal, such as an amplitude or frequency of the pressure signal. As an example, controller 214 can compare the signal characteristic of the pressure signal to predetermined pressure values and determine the pressure associated with the signal characteristic, e.g., in a memory of controller 214 or another device. The pressure setpoint referenced by controller 214 can also be stored in a memory of controller 214 or another device.

Controller 214 alters a pressure in pressure chamber 202 of PRV 200 based on the determined pressure offset (806). For example, controller 214 may alter the pressure by directing compressor 208 to charge pressure chamber 202 and increase the pressure in pressure chamber 202. In addition, or instead, controller 214 may alter the pressure by directing vent valve 210 to vent pressure chamber 202 and decrease the pressure in the pressure chamber. For example, in response to determining the pressure offset indicates the pressure indicated by pressure sensor 212 is greater than the pressure setpoint, controller 214 may alter the pressure by directing vent valve 210 to vent pressure chamber 202 and decrease the pressure in the pressure chamber, causing sensing element 206 to reposition restricting element 204 in a manner that increases a pressure drop of a fluid as it flows through flow area 222. In response to determining the pressure offset indicates the pressure indicated by pressure sensor 212 is less than the pressure setpoint, controller 214 may alter the pressure by directing compressor 208 to charge pressure chamber 202 and increase the pressure in the pressure chamber, causing sensing element 206 to reposition restricting element 204 in a manner that decreases a pressure drop of a fluid as it flows through flow area 222.

As a result of the pressure in pressure chamber 202 being altered (806), controller 214 causes sensing element 206 in fluid communication with pressure chamber 202 to move (808), where movement of sensing element 206 alters flow area 222 between valve inlet 224 and valve outlet 226. As discussed above, the size (e.g., volume) of flow area 22 affects the fluid pressure in the fluid circuit including PRV 200. For example, increasing flow area 222 can decrease pressure through PRV 200 and decreasing flow area 222 can increase pressure through PRV 200.

In one or more examples, functions described herein may be implemented in hardware, software, firmware, or any combination thereof. For example, the various components and functions of FIGS. 1-8 may be implemented in hard-

ware, software, firmware, or any combination thereof. If implemented in software, the functions may be stored on a tangible computer-readable storage medium and executed by a processor or hardware-based processing unit.

Instructions may be executed by one or more processors, such as one or more DSPs, general purpose microcontrollers, ASICs, FPGAs, or other equivalent integrated or discrete logic circuitry. Accordingly, the term "processor," as used herein, such as may refer to any of the foregoing structure or any other structure suitable for implementation of the techniques described herein. Also, the techniques could be fully implemented in one or more circuits or logic elements.

The techniques of this disclosure may be implemented in a wide variety of devices or apparatuses, including a wireless handset, an integrated circuit (IC) or a set of ICs (e.g., a chip set). Various components, modules, or units are described in this disclosure to emphasize functional aspects of devices configured to perform the disclosed techniques, but do not necessarily require realization by different hardware units. Rather, as described above, various units may be combined in a hardware unit or provided by a collection of interoperative hardware units, including one or more processors as described

Various examples have been described. These and other examples are within the scope of the following claims.

What is claimed is:

1. A pressure regulating valve comprising:
  - a pressure chamber of the pressure regulating valve;
  - a compressor configured to establish fluid communication with the pressure chamber;
  - a vent valve configured to establish fluid communication with the pressure chamber;
  - a pressure sensor configured to generate a signal indicative of a pressure; and
  - a controller configured to:
    - determine a pressure setpoint for the pressure;
    - determine the pressure based on the signal generated by the pressure sensor;
    - compare the pressure setpoint and the pressure; and
    - increase or decrease pressure in the pressure chamber based on the comparison of the pressure setpoint and the pressure, wherein the controller is configured to increase the pressure in the pressure chamber by at least controlling the compressor to increase pressure in the pressure chamber, and wherein the controller is configured to decrease the pressure in the pressure chamber by at least controlling the vent valve to decrease pressure in the pressure chamber.
2. The pressure regulating valve of claim 1, further comprising:
  - a restricting element; and
  - a sensing element in fluid communication with the pressure chamber,
 wherein the sensing element is configured to position in response to the pressure in the pressure chamber, and wherein the sensing element is configured to influence a position of the restricting element.
3. The pressure regulating valve of claim 2, wherein the restricting element comprises a valve disc, and wherein the pressure regulating valve further comprises:
  - a valve stem attached to the valve disc;
  - a valve seat; and
  - a flow area between the valve disc and the valve seat, wherein the sensing element is configured to translate

the valve stem and alter the flow area in response to the controller increasing or decreasing pressure in the pressure chamber.

4. The pressure regulating valve of claim 3, wherein the sensing element is configured to translate the valve stem and reduce the flow area in response to the controller increasing pressure in the pressure chamber, and wherein the sensing element is configured to translate the valve stem and increase the flow area in response to the controller decreasing pressure in the pressure chamber.

5. The pressure regulating valve of claim 3, wherein the sensing element is configured to translate the valve stem and increase the flow area in response to the controller increasing pressure in the pressure chamber, and wherein the sensing element is configured to translate the valve stem and decrease the flow area in response to the controller decreasing pressure in the pressure chamber.

6. The pressure regulating valve of claim 2, further comprising a spring element configured to translate the valve stem and reduce the flow area.

7. The pressure regulating valve of claim 1, further comprising a valve inlet and a valve outlet, wherein the pressure regulating valve is configured to fluidly isolate the pressure chamber from the valve inlet and the valve outlet.

8. The pressure regulating valve of claim 1, wherein the controller comprises a Proportional-Integral-Derivative (PID) controller, wherein the PID controller is configured to compare the pressure setpoint and the pressure, and use the pressure as a process variable.

9. The pressure regulating valve of claim 1, wherein the controller is configured to:
  - receive a communication signal; and
  - determine the pressure setpoint by at least associating the communication signal with a specific pressure.

10. The pressure regulating valve of claim 1, wherein the controller is configured to:
  - receive a fluid leak signal; and
  - increase or decrease the pressure in the pressure chamber to cause the sensing element to influence the restricting element to reduce or cease a flow through the pressure regulating valve in response to receiving the fluid leak signal.

11. The pressure regulating valve of claim 1, wherein the pressure regulating valve comprises at least one of a poppet valve, a needle valve, a gate valve, a globe valve, a double-ported valve, or a spool valve.

12. A pressure regulating system comprising:
  - a valve comprising:
    - a pressure chamber;
    - a valve inlet;
    - a valve outlet;
    - a sensing element in fluid communication with the pressure chamber, wherein the sensing element is configured to displace when a pressure in the pressure chamber increases or decreases; and
    - a restricting element mechanically coupled to the sensing element, wherein the restricting element is configured to alter a flow area between the valve inlet and the valve outlet when the sensing element displaces; and
  - a controller configured to:
    - determine a pressure setpoint,
    - receive a signal indicative of a pressure,
    - compare the pressure setpoint and the signal indicative of the pressure,
    - control, based on the comparison, a compressor to increase the pressure in the pressure chamber and



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displace the sensing element and cause the restricting element to alter the flow area, and  
control, based on the comparison, a vent valve to decrease the pressure in the pressure chamber and displace the sensing element and cause the restricting element to alter the flow area.

13. The pressure regulating system of claim 12, wherein the sensing element comprises a diaphragm, a piston, or a diaphragm and a piston.

14. The pressure regulating system of claim 12, wherein the pressure comprises the pressure at the valve inlet, the system further comprising a pressure sensor configured to generate the signal indicative of the pressure at the valve inlet.

15. The pressure regulating system of claim 12, further comprising a main valve comprising a main valve stem, wherein the valve is a pilot valve configured to control a position of the main valve stem.

16. The pressure regulating system of claim 12, wherein the restricting element comprises a valve disc, and wherein the valve further comprises a valve stem mechanically coupling the valve disc to the sensing element, wherein the valve disc is configured to alter the flow area between the valve inlet and the valve outlet when the sensing element displaces.

17. The pressure regulating system of claim 12, further comprising:

the compressor;

the vent valve; and

a pressure sensor configured to generate the signal indicative of the pressure at the valve inlet.

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18. A method of regulating a pressure, the method comprising:

receiving, by a controller, a pressure signal indicative of a pressure;

determining, by the controller, the pressure based on the signal;

determining, by the controller, a pressure offset between the pressure and a pressure setpoint;

increasing, by the controller, a pressure in a pressure chamber of a pressure regulating valve based on the pressure offset by at least causing a compressor to increase the pressure in the pressure chamber; and

decreasing, by the controller, the pressure in the pressure chamber of the pressure regulating valve based on the pressure offset by at least causing a vent valve to vent the pressure chamber and decrease the pressure in the pressure chamber,

wherein increasing or decreasing the pressure in the pressure chamber causes movement of a sensing element in fluid communication with the pressure chamber, and wherein the movement of the sensing element alters a flow area between a valve inlet and a valve outlet.

19. The method of claim 18, wherein receiving the pressure signal comprises receiving, by the controller, the pressure signal from a pressure sensor, wherein the pressure signal is indicative of a pressure at the valve inlet.

20. The method of claim 18, wherein movement of the sensing element alters the flow area by at least causing a restricting element to translate a valve stem and a valve disc, wherein the valve disc is in fluid communication with the flow area.

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